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Simulation of Pesticide Movement on Small Agricultural Watersheds

ESL, Inc, Sunnyvale, Calif

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SCRAM predictions of these physical processes are compared to experimental data furnished by the Southeast Environmental Research Laboratory in cooperation with the Southern Piedmont Conservation Research Center. Simulated runoff for two small watersheds (less than 3 hectares) near Athens, Georgia, agrees reasonably well with experimental data. Sediment loss is not as accurately predicted. Predictions of pesticide loss in the runoff and on the sediment are in reasonable agreement with experimental data if allowance is made for the effects of inaccurately predicting sediment loss.

Simulated pesticide movement in the soil profile differs from experimental measurements at the surface and below 10 cm. Simulated degradation rates are below measured rates early in the season but are in closer agreement by the end of the season. Volatilization losses for a single pesticide agree qualitatively with measured values. The evapotranspiration model was not evaluated directly.

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SIMULATION OF PESTICIDE MOVEMENT ON SMALL AGRICULTURAL WATERSHEDS

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ABSTRACT

Simulation of Contaminant Reactions and Movement (SCRAM) is a computer simulation designed to predict the movement of pesticides from agricultural lands. SCRAM is composed of deterministic submodels which describe the following physical processes: infiltration, percolation, evaporation, runoff, sediment loss, pesticide adsorption and desorption in the soil profile, pesticide microbial degradation in the soil profile, and pesticide volatilization.

SCRAM predictions of these physical processes are compared to experimental data furnished by the Southeast Environmental Research Laboratory*in cooperation with the Southern Piedmont Conservation Research Center. Simulated runoff for two small watersheds (less than 3 hectares) near Athens, Georgia, agrees reasonably well with experimental data. Sediment loss is not as accurately predicted. Predictions of pesticide loss in the runoff and on the sediment are in reasonable agreement with experimental data if allowance is made for the effects of inaccurately predicting sediment loss.

Simulated pesticide movement in the soil profile differs from experimental measurements at the surface and below 10 cm. Simulated degradation rates are below measured rates early in the season but are in closer agreement by the end of the season. Volatilization losses for a single pesticide agree qualitatively with measured values. The evapotranspiration model was not evaluated directly.

Further testing and development is recommended to improve the sediment, degradation, and adsorption-desorption models. With additional development SCRAM should prove to be a valuable research tool to increase our understanding of how pesticides and other agricultural pollutants are transported to the aquatic environment.

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Mr. M.S. Bull	Programming and computer plotting.
Dr. R.S. DeZur	Implementation of the sediment model.
Mr. R.G. Donald	Simulation structure and programming.
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SECTION I
CONCLUSIONS

1. Simulation of Contaminant Reactions and Movement (SCRAM), a computer simulation based upon deterministic submodels, is a valuable tool in understanding how pesticides are transported from agricultural lands to the aquatic environment.

2. The use of deterministic submodels (rather than statistical submodels) significantly increases the amount of computer storage and processing time required to simulate a typical growing season. SCRAM requires 372,000 words of storage on an IBM 370/145 and takes approximately two hours of CPU time to simulate a 3-4 month growing season. However, the advantages of being able to predict the pesticide distribution in the soil profile and soil moisture profile are important in understanding how pesticides are transported to the aquatic environment.

3. Simulation of surface runoff from small watersheds near Athens, Georgia, agrees reasonably well with experimental measurements. Additional refinement of the hydrologic submodel will improve the results for the winter storms.

4. Sediment loss predictions do not agree with experimental measurements. The reasons for the disagreement may reflect (1) inadequacies of the modified Foster-Meyer submodel, and/or (2) the physical design of the experimental watersheds, which alters the natural flow of runoff.

5. Simulated diphenamid loss in the runoff water and on the sediment for a small watershed of 2.70 hectares agrees with experimental measurements. Atrazine loss from a 1.4 hectare plot was not accurately predicted, primarily because of low runoff and sediment loss predictions.

6. Pesticide movement in the soil profile depends on the amount of water infiltrated, and percolated, and on the rate of evaporation and transpiration. Accordingly, differences between simulated and experimental pesticide distributions in the soil profile depend on many processes other than the pesticide adsorption/desorption submodel. Nevertheless, some general observations are possible:

(a) Some diphenamid is transported below five centimeters more rapidly than predicted.

(b) Some diphenamid remains in the upper five centimeters longer than the predicted time.

(c) Initial movement of atrazine into the soil profile is more rapid than predicted.

(d) Regardless of the pesticide type, the simulated rate of removal from the soil surface is too rapid.

7. Simulated degradation of diphenamid is in qualitative agreement with experimental results. Simulated atrazine degradation did not agree with experimental measurements. Adjustments to the degradation submodel, plus the addition of a soil temperature submodel, would improve the results.

8. Simulated volatilization losses of trifluralin are somewhat unsatisfactory. Total simulated losses agree with experimental losses only for unexpectedly large values for the diffusion coefficient. Trifluralin movement in the soil profile is in close agreement with experimental results.

9. Further development and testing of SCRAM is required before it can be used effectively to predict the water quality impact resulting from applications of pesticides to agricultural lands.

10. Simulation can be a valuable technique for developing effective controls to reduce pesticide pollution of the aquatic environment. Parameters determined from laboratory tests on pesticides can be used to simulate the environmental impact. Quantitative comparisons between pesticides can be developed for the same simulated conditions. Pesticides which have a high potential for transport may be restricted to uses where there is little threat to the aquatic environment.

SECTION II
RECOMMENDATIONS

In the future, nonpoint sources of water pollution will be an increasingly significant factor in our nation's ability to meet the water quality standards specified in the 1972 Federal Water Pollution Control Act. Simulation is potentially a valuable technique for quantifying the degradation of water quality by nonpoint sources and for developing effective controls to reduce nonpoint source pollution.

Simulation of pesticide movement from agricultural lands using deterministic (as opposed to statistical) models appears feasible based upon the results of this project. Development and testing of a large computer simulation program like SCRAM leads naturally to the following recommendations:

1. Perform additional testing of the entire simulation using existing experimental data. The results would provide the necessary information to make changes and improvements to SCRAM.

2. The hydrologic model should be modified to include interflow and groundwater flow. Changes should also be made to account for different hydrologic properties as a function of soil depth.

3. Modifications should be made to the evapotranspiration model to improve the algorithm which extracts and redistributes water in the soil profile.

This algorithm affects the initial soil moisture profiles for subsequent storms, thereby altering runoff volumes, runoff rates, and sediment loads. Additionally, it indirectly influences all the pesticide predictions by altering the moisture profile used to degrade the pesticide and by affecting infiltration velocities that determine adsorption-desorption profiles, thus altering the pesticide in the runoff water and sediment.

4. A soil temperature predictive model should be developed and incorporated into SCRAM to predict a soil temperature profile as a function of such external variables as crop canopy and meteorological conditions. It is impractical to use experimental data, which will generally not be available. Soil temperature profile is an input to the degradation model.

5. The sediment model should be examined in detail to determine why the simulated results do not agree with the experimental results. This model is critical to the overall success of the simulation. More testing should be done and the impact, if any, of the present experimental procedure on sediment loss should be determined.

6. The pesticide adsorption-desorption model should be modified to incorporate a pesticide application algorithm. The pesticide cannot be assumed to dissolve at the surface during the first rainfall. Also, the present model requires soil depth increments of less than 0.5 centimeters, which is incompatible with other

submodels. Finally, this model should be modified to permit pesticide degradation and allow for pesticide in a crystalline state.

7. SCRAM should be tested on watersheds larger than three hectares. As part of this effort additional models and algorithms should be developed to define the interrelationships between each zone on the watershed and to permit different crop types and conservation management practices on each zone.

8. Finally, the applicability of SCRAM to other types of agricultural pollutants and other nonpoint sources of pollution should be investigated and implemented if appropriate.

SECTION III
INTRODUCTION

BACKGROUND DATA

Pesticides - with their capacity to kill insects, weeds, rodents, and fungus - combine with machinery, fertilizers, and new seed types to make American farmers the most productive on earth. Economic savings due to increased crop production have been estimated at more than 4.5 billion dollars per year. The use of chemical pesticides has also stirred intense controversy and concern over the real and presumed hazards they create in the environment.

Pesticides differ widely in chemical and toxicological characteristics. Presently there are thousands of registered formulations incorporating nearly 900 different chemicals. U.S. production of pesticides totaled 0.5 billion kilograms in 1971.[1] Trends in production indicate an annual increase of 15 percent, plus predictions of increasing demand during the next decade.[2]

The pesticides of greatest concern are those that are persistent for long periods and therefore accumulate in the environment. Chlorinated hydrocarbon insecticides are a notable example. Regardless of how they enter organisms, chlorinated hydrocarbons have an adverse effect on the nervous system.[3] Mild concentrations cause headaches, dizziness, gastrointestinal disturbances, numbness and weakness of the extremities, hyperirritability, and apprehension. Higher concentrations are associated with muscular fasciculations spreading throughout the body, followed in some cases by convulsions and death.[4]

Due to the absence of human volunteers, most safe human exposure levels are derived from studies with mice. In one study using tumorsusceptible mice, increased incidences of tumors were produced with large doses of DDT (46.4 mg/kg/day).[5] Another study with mice over five generations showed a greater incidence of malignancies and leukemia after the second generation.[6] Other studies involving a variety of chlorinated hydrocarbons have demonstrated that some compounds are highly toxic while others produced no effects in mammals (rats and dogs).

Organophosphorus (e.g., parthion) and carbonate insecticides ingested over prolonged periods result in the dysfunction of cholinesterase (destruction of acetylcholine, which prevents reexcitation of muscle fiber) of the nervous system.[8] Studies involving the toxicity of the chlorophenoxy herbicides (2,4-D; 2,4,5-T; etc.) are inconclusive, but apparently adverse effects are associated with very high doses.[2]

Documented ill effects of pesticides are not limited to humans but include birds, shellfish, wildlife, and beneficial insects. Between 1966 and 1968 more than 30 percent of the bald eagles found dead in the United States had lethal levels of dieldrin in the brain.[9] Many of the 48 bald eagles found dead in Wyoming in 1971 had been killed by thallium, a toxic poison used in animal control.[9] Coho salmon, lake trout, chubs, and lake herring from Lake Michigan are not considered acceptable for sale in interstate commerce because of high levels of DDT.[4]

An added complication exists in aquatic organisms which accumulate ingested pesticides. The transfer of pesticide residues from prey to predator ultimately results in residues in the higher trophic levels many thousand times greater than ambient water levels (biomagnification). The result may be lethal to large predatory birds and mammals.[9]

Thus, while pesticides significantly contribute to agricultural productivity, it has become apparent that the danger to man and the environment may outweigh the benefits. Increased knowledge of the effects of pesticides on ecosystems has resulted in pressure for new legislation governing the use of pesticides.

LEGISLATIVE BACKGROUND

Federal responsibility for the control of pesticides was transferred primarily to the United States Environmental Protection Agency (EPA) when it was established in December, 1970. Several major Federal laws are available to the EPA for controlling pesticides. In 1972 Congress passed the Federal Environmental Pesticide Control Act[10] (FEPCA) which amended the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947. Portions of the Federal Water Pollution Control Act[11] (FWPCA) (as amended in 1972) and of the Federal Food, Drug, and Cosmetic Act[12] are applicable to pesticide control.

FEPCA continues FIFRA's use of product registration as a basis for control. A full sample label and product formula must be submitted. The label must contain a description of the product's capability and clear directions for its use. Manufacturers must show that the product can perform its intended functions without causing unreasonable adverse effects on the environment.

A pesticide may be registered for general or restricted use depending on the product's possible unreasonable adverse effects on the environment. A product is registered for general use if it is unlikely to have adverse effects if properly used. Pesticides which may produce adverse effects are registered for restricted use and may only be used under the direction of a certified applicator. Under this classification of pesticides, denial of registration would only be possible if a pesticide would cause unreasonable adverse effects on the environment regardless of regulatory restrictions. However, FEPCA also provides for a change in classification or cancellation after initial registration if evidence subsequently develops that the pesticide generally causes unreasonably adverse effects on the environment.

FEPCA also extends regulation to the manufacturer's premises, which must be registered with the EPA. This requirement provides information on the production and distribution of pesticides. Inspection of registered premises may occur upon written notice to the owner, whether or not a violation of the Act's provisions is suspected.

Under the Food, Drug and Cosmetic Act, pesticides which are used in a manner which leaves a residue on crops that provide food for man or animal are subject to tolerance specifications. Manufacturers are required to submit information to support the amount of pesticide residue (tolerance) which can safely remain on the crop after harvest. Where the supporting data is inadequate or a health hazard exists, zero tolerances may be specified.

The amendments to the Federal Water Pollution Control Act of 1972 contain several provisions directed toward nonpoint source pollution control. Nonpoint sources are not defined in the Act but are cited in several Sections and include agriculture, silviculture, mining, and construction activities. Pesticides are a predominant pollutant from nonirrigated farming and hence the nonpoint source provisions of FWPCA are available to the EPA to control pesticide pollution.

EPA's efforts to control nonpoint sources involves two approaches. The first is the identification and application of the best practical control technologies through Federal, State, and local mechanisms. The second element is a broad based effort to assess and control the water quality impact of nonpoint sources. These efforts should help to implement farm management practices at the local level, such as terracing, diversions, contouring, stripcropping, crop rotations, and cover crops which reduce water erosion on farm lands.[1]

In order to fully implement FWPCA 1972, the EPA will need to develop and verify procedures for (1) estimating pesticide discharges from agricultural sources, and (2) predicting reductions in pesticide discharges resulting from implementation of specific controls. A first step in this process will require an understanding of how pesticides are transported from agricultural lands to the aquatic environment.

MOVEMENT OF AGRICULTURAL PESTICIDES TO THE AQUATIC ENVIRONMENT

The pathways pesticides follow from the time of application to argricultural lands until they reach the aquatic environment have been delineated in detail elsewhere.[1,13] Briefly, there are two major pathways: dissolution in runoff water, and adsorption on sediment carried by runoff water. Depending on the pesticide, rate and mode of application, and soil type, one or both mechanisms may be present.[14] Some pesticides are highly volatile and are not readily transported in runoff water or on sediment. Nevertheless, they may be deposited in the water systems. Other pesticides which are persistent may be leached from the soil as rainwater percolates through the soil. Eventually these pesticides may reach groundwater and be transported into the rivers and lakes. Finally, pesticides may be directly applied to waterbodies via poor application techniques.

Unfortunately, although the potential pathways for pesticide movement are relatively easy to identify, their relationship and significance to each pesticide is not easily quantified. Rainfall occurs without producing runoff or heavy rainfall and runoff, may occur shortly after application. Some pesticides are surface applied and readily interact with runoff water; others are incorporated into the soil. Adsorption of some pesticides in the soil is so strong that very little pesticide appears in the runoff water. Tillage systems and conservation practices including terraces, diversions, stripcropping, and contouring have a significant impact on the amount of runoff and soil erosion. Pesticides on the surface and in the soil undergo microbial, chemical, and photochemical degradation. These processes in turn are influenced by solar radiation, relative humidity, and soil moisture. Volatilization depends on the pesticide type, soil moisture, soil temperature, and wind velocities.

Understanding these phenomenon and developing effect techniques for controlling pesticide contamination of the environment can be accomplished with the aid of systems analysis and mathematical modelling.

SYSTEMS ANALYSIS AND MATHEMATICAL MODELLING OF PESTICIDE TRANSPORT

The systems analysis approach to problem solving involves a number of more or less standard steps:

1. Formulation of the problem.

2. Construction of mathematical models that describe the significant variables of the system.

3. Development of a simulation structure compatible with selected mathematical models.

4. Collection of data to allow estimation of the model parameters.

5. Testing of the model, proposed solutions and sensitivity analysis of the parameters, i.e., simulation of the system.

6. Identification of the best solutions.

The first step formulation of the pesticide problem has been reviewed in this section and is covered in detail in the references.[1,4,13] Construction of mathematical models to describe runoff, sedimentation, and pesticide movement is discussed in this report. The simulation structure developed to accommodate the mathematical models is discussed in Section V. Data collection was performed independently but is presented in Section IV. The initial testing of the simulation and models and the sensitivity analysis comprise Section VII. The final step, identification of the best control methodologies to reduce pesticide contamination of the aquatic environment, will require additional model development and simulation in the future.

SECTION IV

EXPERIMENTAL PROGRAM CONDUCTED BY EPA/USDA

GENERAL

SCRAM was developed as part of a large program conducted by the U.S. Environmental Protection Agency's Southeast Environmental Research Laboratory (SERL). Data to support the model development came from an extensive field investigation effort conducted by SERL in cooperation with Southern Piedmont Conservation Research Center of the Agricultural Research Service (ARS), U.S. Department of Agriculture (USDA). This Section summarizes the joint EPA/USDA field program to facilitate the understanding of the entire project.

EPA/USDA FIELD SITES

The field program was started in 1972 with the establishment of two watersheds, two small scale plots, and twelve attenuation plots. The program was expanded with two additional watersheds during 1973. The watersheds (P-01, P-02, P-03, P-04), subplots (SP-1, Sp-3), and attenuation plots are within 3.5 kilometers of each other in Oconee County, Georgia (Figure 1). Soils are predominately Cecil Sandy Loam with high acidity and clay content and low organic matter.

Schematics of the four watersheds are shown in Figures 2-5. P-01 is the largest watershed at 2.70 hectares and like P-02 (1.29 ha.) represents poor conservation management practice. P-03 (1.20 ha.) and P-04 (1.38 ha.) are representative of good conservation management practice with graded terraces, grassed waterways, and aerially seeded winter rye crop.

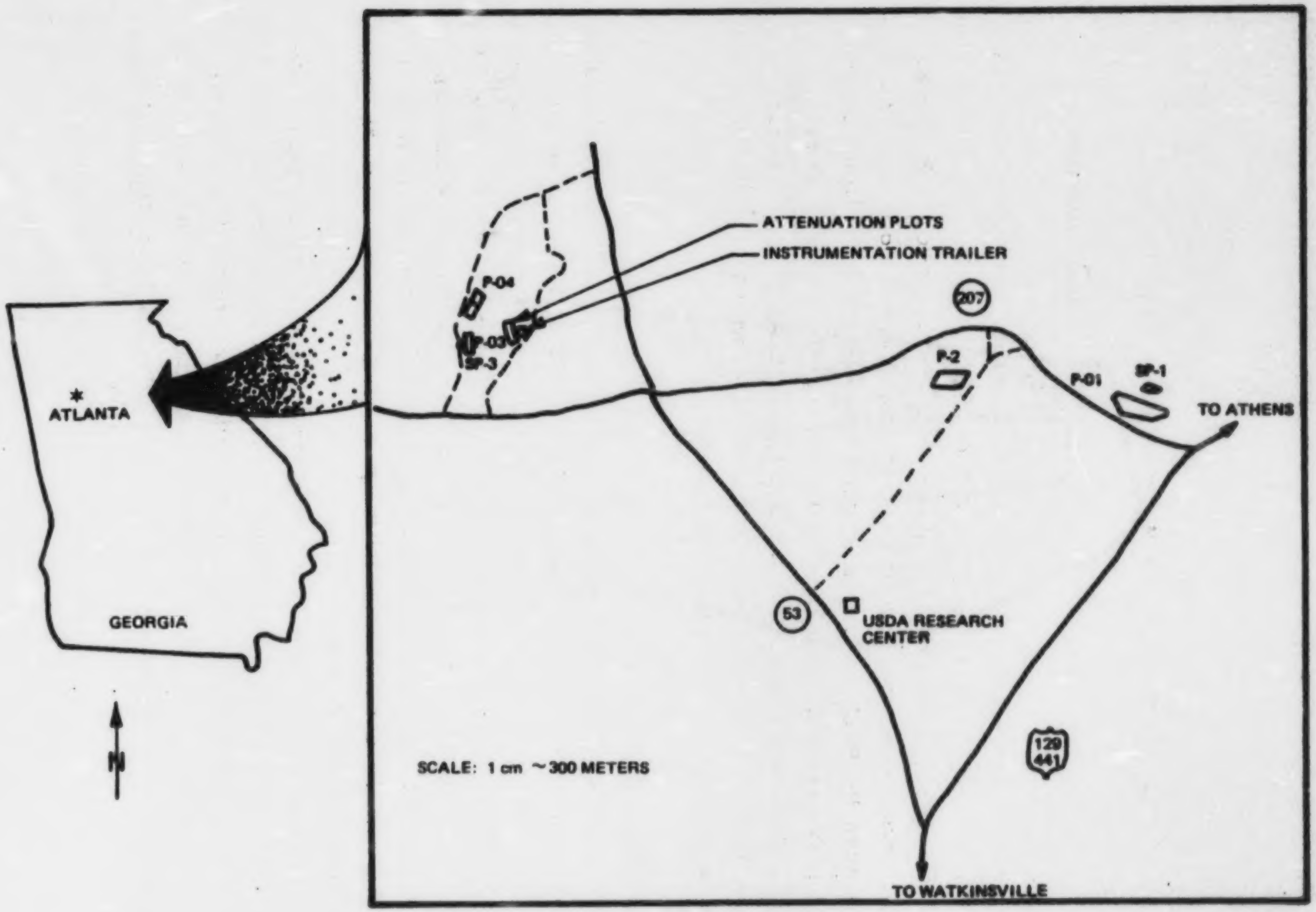

ATLANTA
GEORGIA
N
ATTENUATION PLOTS
INSTRUMENTATION TRAILER
P-04
P-03
SP-3
207
P-2
P-01
SP-1
TO ATHENS
53
USDA RESEARCH CENTER
129
441
SCALE: 1 cm ~300 METERS
TO WATKINSVILLE

Figure 1. Location of experimental watersheds

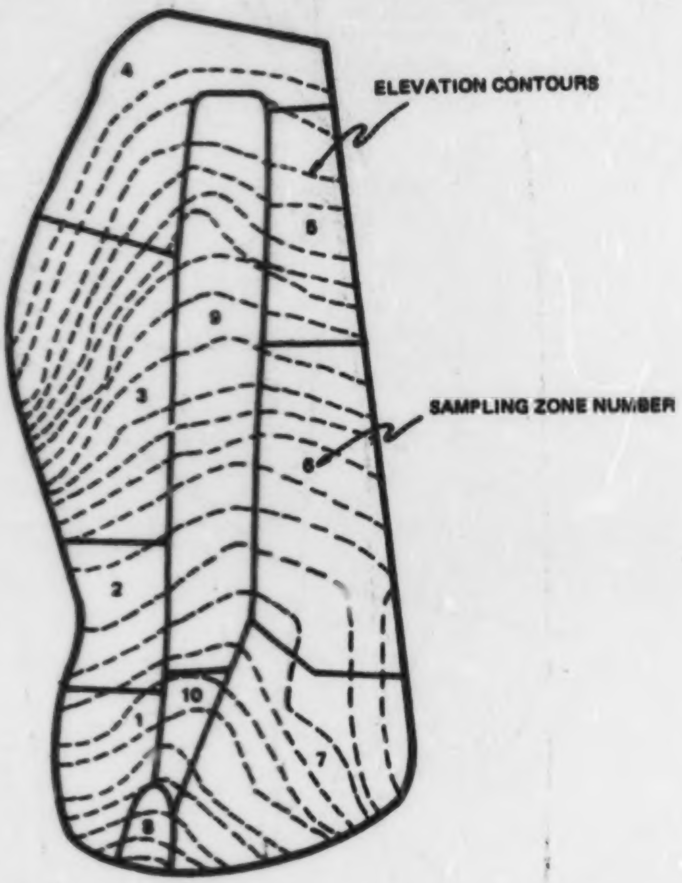

ELEVATION CONTOURS
4
5
9
3
SAMPLING ZONE NUMBER
6
2
10
1
7
8

Figure 2. Schematic of the P-01 watershed (2.70 hectares)

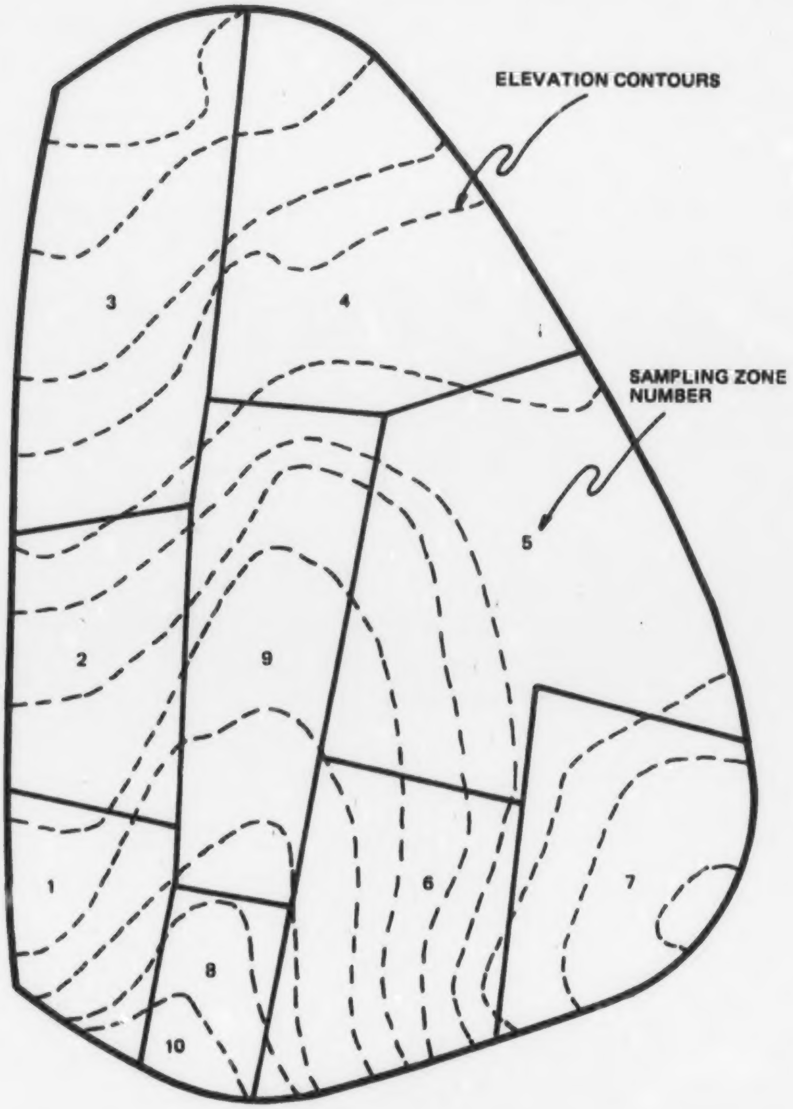

ELEVATION CONTOURS
SAMPLING ZONE NUMBER
3
4
5
2
9
1
6
7
8
10

Figure 3. Schematic of the P-02 watershed (1.29 hectares)

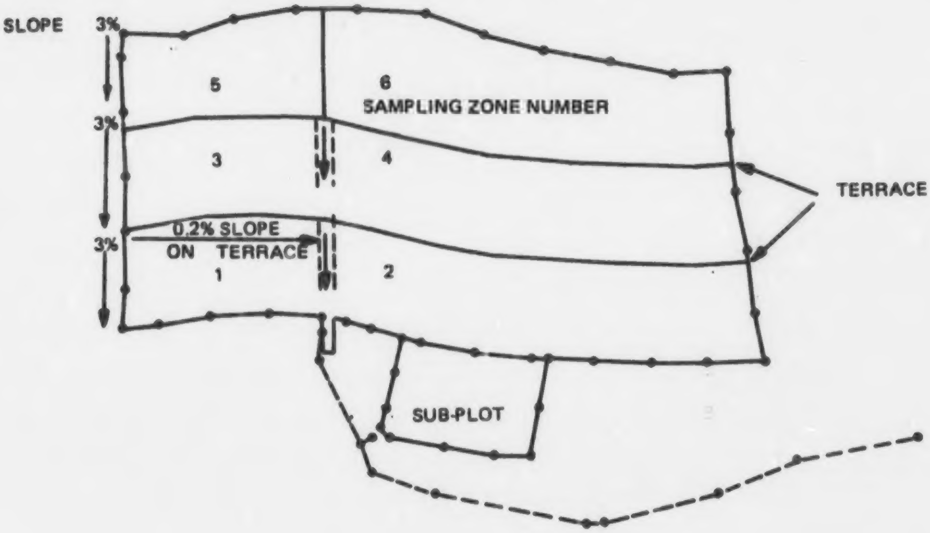

SLOPE 3%
3%
3%
5
6
SAMPLING ZONE NUMBER
3
4
TERRACE
0.2% SLOPE ON TERRACE
1
2
SUB-PLOT

Figure 4. Schematic of the P-03 watershed (1.20 hectares)

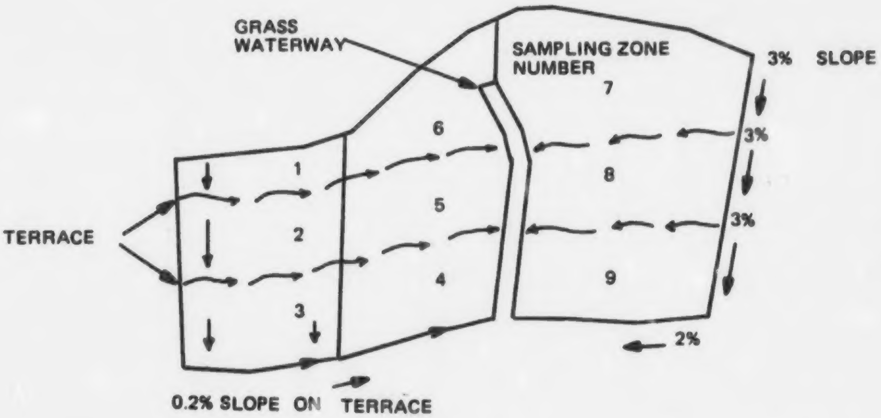

GRASS WATERWAY
SAMPLING ZONE NUMBER
3% SLOPE
7
6
3%
1
8
5
3%
TERRACE
2
4
9
3
2%
0.2% SLOPE ON TERRACE

Figure 5. Schematic of the P-04 watershed (1.38 hectares)

P-01 and P-03 were planted in soybeans and three herbicides were used: paraquat, diphenamid, and trifluralin. Atrazine and paraquat were applied to P-02 and P-04, which were planted in corn. Both subplots were planted in soybeans and paraquat, diphenamid, and trifluralin were applied. Table 1 summarizes the field site parameters for 1973 and Table 2 presents the pertinent herbicide properties.

EXPERIMENTAL PROCEDURE (WATERSHEDS)

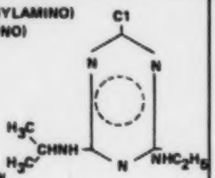
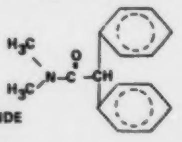
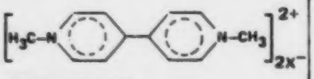
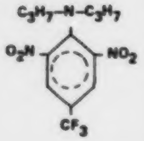
The watersheds were primarily designed to provide data on pesticide movement during runoff producing events. Each watershed was equipped with a recording rain gauge. Runoff from the watersheds was gauged with a 0.762 meter stainless steel H-flume.[15] During event runoff, samples were collected with a traversing D.C. powered slot and a stationary splitter. The runoff sample was allowed to flow by gravity to an adjacent refrigerated collection compartment. The samples were collected in 11.35 liter stainless steel beakers positioned on a rotating platform. All conveyance and collection vessels were fabricated with stainless steel to prevent pesticide sorption. A float mechanism was constructed to energize (D.C. power) the rotating beaker platform at sample completion. Relay circuits were fabricated with the float device to record the sample collection time and flume stage height. As described by Fleming and Leonard,[16] each sample was sub-divided for separate chemical and sediment analysis. Sediment concentration was determined for each sample. The chemical analysis involved sediment separation for pesticide analysis in both the water and sediment fraction.[17,18]

Table 1. EPA/USDA FIELD EXPERIMENTAL TEST SITE DATA FOR 1973

	WATERSHEDS				SUB-PLOTS		ATTENUATION
DESCRIPTORS	P-01	P-02	P-03	P-04	SP-1	SP-3	PLOTS
AREA	2.70 ha	1.29 ha	1.20 ha	1.28 ha	9 X 22 m	26 X 39 m	6 X 9 m
NUMBER OF CORE SAMPLING AREAS	10	10	8	11	1	1	1/PLOT
CONSERVATION PRACTICE	–	–	TERRACES & GRASS WATERWAYS	TERRACE & GRASS WATERWAYS	–	–	–
SLOPE	2–6%	2–4%	3% INTO TERRACE 0.2% ALONG TERRACE		–	–	FLAT
CROP	SOYBEANS	CORN	SOYBEANS	CORN	SOYBEANS	SOYBEANS	SOYBEANS
PLANT DATE	JUNE 13, 1973	MAY 11, 1973	JUNE 15, 1973	MAY 11, 1973	JUNE 13, 1973	JUNE 15, 1973	JUNE 5, 1973
MATURITY DATE	SEPT 12, 1973	AUG 16, 1973	SEPT 12, 1973	AUG 16, 1975	SEPT 12, 1973	SEPT 12, 1973	SEPT 12, 1973
PESTICIDES AND APPLICATION RATE	PARAQUAT 1.12 kg/ha	PARAQUAT 1.12 kg/ha	PARAQUAT 1.12 kg/ha	PARAQUAT 1.12 kg/ha	SAME AS P-01	SAME AS P-03	PARAQUAT*
	DIPHENAMID 3.36 kg/ha	ATRAZINE 3.36 kg/ha	DIPHENAMID 3.36 kg/ha	ATRAZINE 3.36 kg/ha	SAME AS P-01	SAME AS P-03	DIPHENAMID*
	TRIFLURALIN 1.12 kg/ha (INCORPORATED)		TRIFLURALIN 1.12 kg/ha (INCORPORATED)		SAME AS P-01	SAME AS P-03	TRIFLURALIN* (INCORPORATED)
CHLORIDE		YES		YES			
FERTILIZER APPLICATION DATE & RATE WASHOUT REAPPLICATION DATE/RATE	5-10-15 ON MAY 22, 1973 420 kg/ha YES JUNE 4, 1973 560 kg/ha	6-6-24 ON MAY 11, 1973 840 kg/ha NO JULY 23, 1973 112 kg/ha SIDE DRESSING	5-10-15 ON MAY 22, 1973 420 kg/ha JUNE 4, 1973 500 kg/ha		SAME AS P-01	SAME AS P-03	5-10-15 440 kg/ha

*FOUR PLOTS WERE CONTROL WITH NO HERBICIDE APPLICATION,
FOUR APPLICATIONS WERE THE SAME AS P-01 AND P-03, AND
FOUR APPLICATIONS WERE AT ONE-HALF THE P-01 AND P-03 RATES.

Table 2. PROPERTIES OF HERBICIDES APPLIED ON EPA/USDA TEST SITES

HERBICIDE	PHYSICAL PROPERTIES	MELTING POINT	WATER SOLUBILITY	VAPOR PRESSURE
2–CHLORO–4–(ETHYLAMINO) –6–(ISOPROPYLAMINO) –S–TRIAZINE  C/N*: ATRAZINE T/N: AATREX 80W M/F: $C_8H_{14}ClN_5$	WHITE CRYSTALLINE SOLID MOLECULAR WEIGHT 215.7	173° TO 175°C	33 ppm	
N,N – DIMETHYL–2,2 DIPHENYLACETAMIDE  C/N: DIPHENAMIDE T/N: ENIDE M/F: $C_{16}H_{17}NO$	WHITE TO OFF-WHITE CRYSTALLINE SOLID. NO APPRECIABLE ODOR MOLECULAR WEIGHT 239.3	132° TO 136°C	260 ppm at 27°C	3.0×10^{-7} mm Hg AT 20°C 1.4×10^{-6} mm Hg AT 30°C
4, 4' – BIPYRIDYLIUM–2A, 1,1'–DIMETHYL DICHLORIDE  WHERE $X^- = Cl^-$ OR $CH_3SO_4^-$ C/N: PARAQUAT T/N: GRAMOXONE, ORTHO PARAQUAT M/F: $C_{12}H_{14}N_2X_2$	WHITE CRYSTALLINE SOLID MOLECULAR WEIGHT 186.2 (CATRON)	DECOMPOSES	100%	$< 10^{-6}$ mm Hg AT 27°C
α, α, α– TRIFLUORO–2, 6–DINITRO–N,N–DIPROPYL P–TOLUIDINE  C/N: TRIFLURALIN T/N: TREFLAN M/F: $C_{13}H_{16}F_3N_3O_4$	ORANGE CRYSTALLINE SOLID MOLECULAR WEIGHT 335.3	48°C	<1 ppm	1.99×10^{-4} mm Hg AT 29.5°C

* C/N = COMMON NAME
T/N = TRADE NAME
M/F = MOLECULAR FORMULA

After a runoff event, soil core samples were collected from each watershed to determine the pesticide distribution in the soil profile and to provide mass balance information. Based upon the size of the area, soil properties and slope, sampling units were identified for each test site. A composite sample for each unit was obtained by combining 12-15 discrete samples and mixing. Each of the core samples were subdivided into seven depth increments as follows: 0-1, 1-2.5, 2.5-5.0, 5.0-7.5, 7.5-15, 15-22.5, and 22.5-30 cm.

EXPERIMENTAL PROCEDURE (ATTENUATION PLOTS)

The smaller attenuation plots (6x9 meters) located near the P-03 and P-04 watersheds were highly instrumented to provide detailed data on pesticide attenuation and degradation between runoff events. A PDP8/E minicomputer system housed in an air conditioned trailer was programmed and interfaced to sensors providing data on wind speed, wind direction, solar radiation, relative humidity, air temperature, rainfall, soil temperature, and soil moisture (Table 3). During operation some 53,000 data points were collected and stored on magnetic tape each day. In addition to the automated environmental data, manual systems were employed to collect information on evaporation, rainfall, runoff, sediment loss, and soil moisture content (gypsum block and gravametric).

A stainless steel catchment trough was established at the base of each of the six center plots to collect surface runoff. Runoff from the plots flows by gravity to the collection facility. Runoff coming from the trough moves through a five-to-one splitter into a large holding tank. When this tank is full, overflow is further divided by a ten-to-one splitter. Spillover from this divisor goes to a second holding tank. The total

Table 3. ENVIRONMENTAL PARAMETERS RECORDED WITH THE PDP8/E DATA ACQUISITION SYSTEM ON SIX OF THE ATTENUATION PLOTS

PARAMETER	LOCATION (cm)
Wind Speed (3 Heights)	30.48, 121.9, 304.8
Wind Direction (2 Heights)	121.9, 304.8
Solar Radiation (Up and Down)	182.9
Relative Humidity (2 Heights)	30.48, 121.9
Air Temperature (4 Heights)	2.54, 61.0, 121.9, 304.8
Rainfall (Tipping Bucket)	----
Soil Temperature (7 Depths)	0.0, 1.0, 2.54, 5.08, 15.24, 22.86, 60.96
Soil Moisture (5 Depths)	5.08, 10.16, 15.24, 22.86, 38.1

collecting system's capability is eight inches of runoff. A representative sample was taken from each tank for pesticide analysis in both the water and sediment fraction.

The following sections utilize some of the experimental data (described above) collected by EPA/USDA to test the submodels which are presently incorporated into the SCRAM simulation structure.

SECTION V
SIMULATION STRUCTURE

INTRODUCTION

Simulation is the development and use of models to aid in the evaluation of ideas and to study dynamic systems or situations. A model of a system is anything that is employed to represent the system for some set of purposes. Parts of a system (components) are often regarded as systems or subsystems of the larger system. Thus models which represent subsystems may be referred to as submodels or models if the context is clear.

Models can be divided into three classifications: (1) models which seek to describe the environment in real terms are categorized as "deterministic," (2) "stochastic" models, which incorporate the concepts of risk, probability, and other measures of uncertainty, and (3) "optimization" models, which find the best possible solutions subject to specified constraints.

Deterministic models may be based upon mathematical equations which describe the underlying physical processes. Alternatively, the mathematical equations may be developed empirically. For example, a model used to describe movement (infiltration) of water through the soil surface into the soil profile may start with a differential equation describing fluid flow in a nondeformable media. The solution to the differential equation becomes the infiltration model. By comparison, an empirical model might simply assume that the infiltration rate is inversely proportional to the cumulative infiltration.

SCRAM was developed to simulate the movement of pesticides from agricultural lands to the aquatic environment. Submodels are based upon "first principles"; empiricism is avoided except where knowledge of basic laws is insufficient or the simplification is consistent with project objectives. The choice of models based upon first principles does not imply that these models are always superior to empirical models. However, simulation of pesticide transport based upon empirical models has been described elsewhere[19] and therefore is not a concern of this study.

SIMULATION DESIGN

SCRAM has been designed to provide maximum flexibility for the user. Two features provide this flexibility: the division of the watershed into zones, and the modular nature of the simulation structure.

An important aspect of SCRAM's organization is the provision for watershed zones or subplots. At the present time a unique zone is defined within the watershed if it has uniform topographical features, the same soil type, or the same rainfall rate. As part of the simulation input the user must specify the soil parameters, slope, and rainfall data for each zone. In addition it is necessary to specify how runoff water moves among zones.

SCRAM was designed around a modular format to facilitate the addition of new models for processes not presently modeled and to allow users to substitute and test alternative models for existing models. To the extent possible, each component of the system being modeled is programmed and coded in a separate subroutine. External environmental parameters are stored in a common area of the computer which is accessible to all of the subroutines. Internally generated parameters are also transferred to a common area for access by other subroutines.

The simulation is under the control of an executive program, the Master Scheduler, which schedules and calls all of the subroutines. At the present time SCRAM contains two operational routines and seven functional routines in addition to the Master Scheduler. Operational programs control the input and output during the system simulation. The functional programs correspond to the physical processes of evapotranspiration, water movement, sediment transport, pesticide degradation, pesticide adsorption in the soil profile, pesticide volatilization, and pesticide mass balance (see Figure 6).

A discussion of each of the major programs and associated subroutines follows. Additional details are contained in Section VII and the documentation and program listings in the appendices. The potential application of SCRAM to large watersheds is discussed in the last part of this section.

MASTER SCHEDULER

The Master Scheduler determines the time sequencing of the simulation. By defining the time sequencing of the simulation, the Master Scheduler controls all of the interrelationships among the functional subroutines. Any modification to these relationships or any addition to the set of functional subroutines would require alterations in the Master Scheduler. For example, in the present structure, the evapotranspiration functional subroutine, EVAP, is not called during periods of rainfall or immediately after rainfall ceases. If the user decided to activate evapotranspiration immediately after rainfall ceases, changes would be made to the Master Scheduler, not the EVAP subroutine.

The Master Scheduler initiates and terminates the simulation at user specified times. After starting the simulation, the Master Scheduler calls the input subroutines to read all

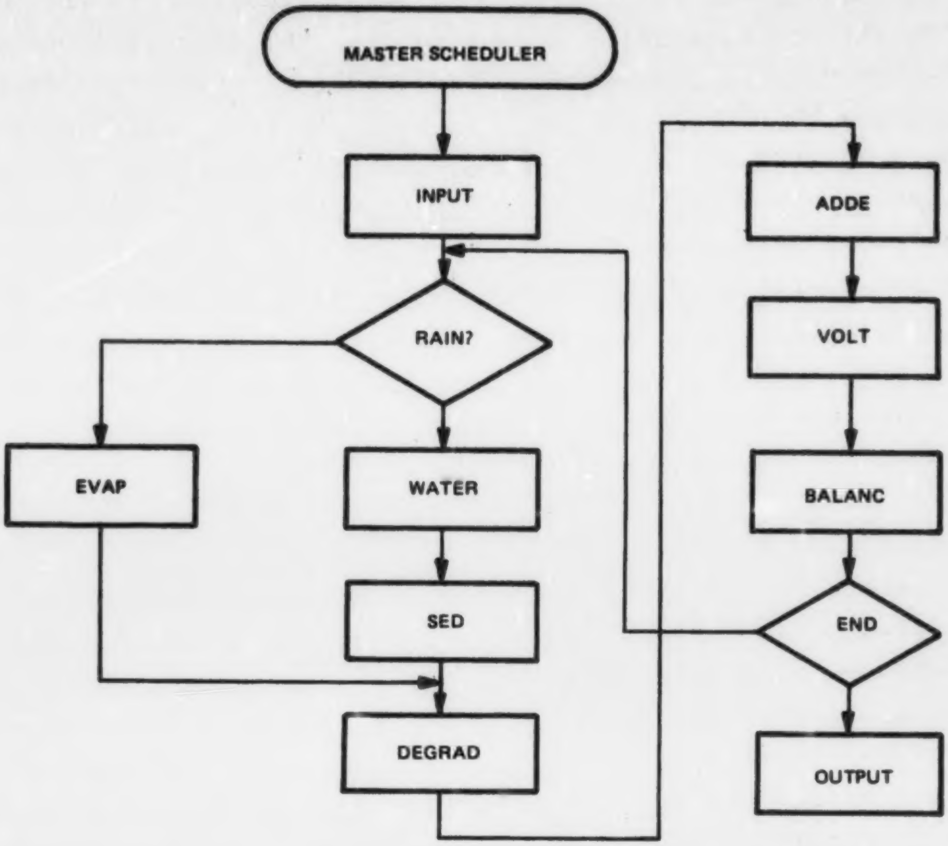

MASTER SCHEDULER
INPUT
RAIN?
EVAP
WATER
SED
DEGRAD
ADDE
VOLT
BALANC
END
OUTPUT

Figure 6. Flowchart of the master scheduler (simplified version)

necessary and available data. It then cycles through functional subroutines according to the environmental conditions being simulated. At present, SCRAM includes a water cycle and a pesticide cycle. After each complete cycle, BALANC, the bookkeeping subroutine, is called. The Master Scheduler then calculates a new simulation time increment, DT, and repeats the cycle among the functional subroutines and BALANC. At user selected intervals, the Master Scheduler calls the output routines to print intermediate results. When the Master Scheduler ascertains that the stop time has been reached, it calls the output routines selected by the user and ends the simulation.

INPUT ROUTINES

Several input subroutines are included in SCRAM to handle the different types of data and the variable startup conditions. During initial startup, simulation input is read from a card reader and stored on disk files. Thereafter the system may be restarted from the disk files. The major input subroutines are associated with reading rain gauge cards, environmental data cards, and simulation parameter cards.

SEQDAT reads all of the rain gauge cards, checks for format errors (calls ERROR), calculates the rainfall rate between rain gauge readings, and writes the rainfall history and rainfall rates onto a disk file. SEQDAT also reads the environmental data on wind speed, temperature, solar radiation, atmospheric pressure, and relative humidity for storage on a disk file.

After SEQDAT, INPUT is called to read all of the simulation parameters (namelist data), including the soil pressure head and diffusivity tables, watershed zonal definition or subplot lineation, and pesticide adsorption-desorption parameters.

All units are converted to the metric system for internal use. Finally, INPUT sets up the simulation start and stop times. If the "warm start" option is utilized, INPUT detects this option and sets up the simulation.

After INPUT, DATINT is called to make the final preparations for starting the simulation. DATIN is called to read the appropriate rainfall cards into common storage. DATEPA reads the appropriate environmental cards into common.

DATEIN is a special routine called by any of the input routines which contain year, month, day, and clock time. All conventional dates are converted to the standard computer Julian time for internal use.

OUTPUT ROUTINES

The output routine provides printed, punched, and disk storage output to the user. The output subroutines are DATOUT, ERROR, OUTPLT, OUTPUT, PRINTH, and SETUP.

DATOUT calculates the calendar date from the Julian date and writes both dates on each printout specified by the user.

ERROR is the output subroutine that prints one of the following error messages and terminates the simulation:

ERROR = 1 input date error
ERROR = 2 time interval error
ERROR = 3 rainfall input data error
ERROR = 4 zone definition error
ERROR = 5 soil type number > 10
ERROR = 6 input temperature error
ERROR = 7 runoff definition error.

OUTPLT produces printer plots on standard line printers for SCRAM. Presently, six plots are produced which are related to runoff and sediment loss from the watershed:

- total runoff (liters) vs time (sec)
- runoff rate (liters/sec) vs time (sec)
- runoff/total rain (percent) vs time (sec)
- sediment rate (kg/hr/hectare) vs time (sec)
- sediment load (kg/hectare) vs time (sec)
- sediment/runoff (kg/liter) vs time (sec).

A punched card option is included to produce card images of the printer plot data on runoff rate (liters/min) vs elapsed time, and sediment loss (kg/min) vs elapsed time. The punched cards were used to generate CALCOMP plots for the major storms.

OUTPUT is the major simulation output subroutine. At user specified time intervals it prints the state of the system. At the specified time interval, state information is printed on the line printer as follows:

- watershed identification data
- date and time
- rainfall rate
- soil moisture profile for each watershed zone down to 15 cm.
- cummulative infiltration
- pesticide distribution in the soil profile
- runoff rate for each zone and at the confluence of the watershed
- rate of sediment loss for each zone and at the confluence of the watershed

- accumulated runoff for each storm
- accumulated sediment loss for each storm
- instantaneous pesticide loss in the runoff
- instantaneous pesticide loss on the sediment
- accumulated pesticide loss in the runoff
- accumulated pesticide loss on the sediment
- evapotranspiration water loss.

If print intervals are not specified, the default value is every simulation time increment. OUTPUT also prints card images of the input data set.

SETUP is a specialized output routine which prints the ESL logo at the beginning of the simulation as an identifying symbol.

BOOKKEEPING

BALANC is SCRAM's bookkeeping subroutine. Its function is to move runoff water and sediment between watershed zones and keep a mass balance on the pesticide. BALANC is called at the end of every time increment before the print routines are called. Results from the BALANC subroutine are used as input to the next cycle through SCRAM.

BALANC moves the runoff produced in every time increment from the originating zone onto neighboring zones, according to the watershed parameters specified by the user. The present structure allows runoff from one zone to move onto a maximum of four adjacent zones. This water movement is limited by a maximum runoff rate which is another watershed parameter supplied to the simulation. Sediment is distributed exactly like the runoff.

Pesticides are moved according to the distribution of runoff and sediment. When this is done, BALANC performs a mass balance on the amount of pesticide in the upper soil layers and in the runoff and on the sediment. In this way, pesticide mass is conserved.

BALANC also performs a mass balance on the amount of water in the simulation system. This is done by comparing the total amount of water entering the system (rainfall) with the total amount in the system (infiltration and storage) and leaving the system (evapotranspiration). This comparison is one of the printout options available to the user.

THE WATER CYCLE

The water cycle (Figure 7) is the major sequence called by the Master Scheduler. During periods of rainfall the infiltration-percolation functional subroutine, WATER, is called. When runoff is generated the sediment functional subroutine, SED, is called. The evapotranspiration function subroutine, EVAP, is called under user specified conditions.

Presently, the WATER and EVAP (evaporation and transpiration) subroutines are mutually exclusive in the simulation structure. The reasons for this are complex but are basically related to simulation constraints and limitations of the pesticide adsorption-desorption model. During periods of evaporation, transpiration, and percolation, the concentration of pesticide in the soil profile is being changed in a variety of ways. At the same time the pesticide degradation model degrades adsorbed and dissolved pesticide. The adsorption-desorption model cannot handle this combination of changes and at the same time conserve pesticide mass.

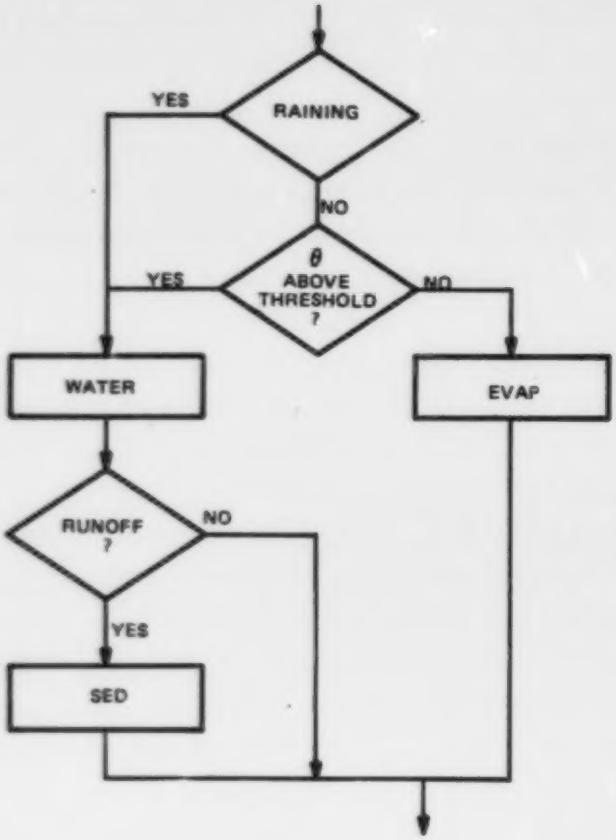

RAINING
YES
NO
θ
ABOVE
THRESHOLD
?
YES
NO
WATER
EVAP
RUNOFF
?
NO
YES
SED

Figure 7. The water cycle

To get around the problem the user must specify a threshold moisture content for the soil surface. When the soil moisture content drops below the threshold, WATER is no longer called. Because EVAP functions by removing soil moisture starting at the top soil layer, the potential error associated with this procedure is minimized.

The WATER functional subroutine is based on the Darcy continuity equation and is discussed in detail in Section VII. WATER predicts the infiltration rate, soil moisture profile, and runoff rate for each watershed zone. The velocity of water movement between soil layers is stored in a common area for use by the adsorption-desorption model. The soil moisture profile is also stored in common for use by the pesticide degradation, volatilization, and evapotranspiration models.

The parameters presently required by WATER include: initial soil moisture profile, rain gauge data for each watershed zone, and the pressure head and soil diffusivity tables for each soil type specified for a particular watershed zone. If the soil parameters are not known, the tables in Section VII can be used to develop reasonable tables for the simulation.

SED is the sediment functional subroutine. Its function is to predict the amount of sediment washed off each watershed zone during a runoff event. This quantity is also directly related to the movement of pesticides. SED is called every simulation time increment for each zone that has runoff water.

Several input values are required by the SED functional subroutine. Presently, the SED functional subroutine receives an input rainfall intensity from the input rainfall history, input watershed parameters, sediment model parameters, and total amount of runoff moved off each subplot during the time increment which is calculated by the WATER functional subroutine and distributed by BALANC. The only output requirement of the SED subroutine is the sediment load at the bottom of each subplot for each time increment.

SCRAM presently employes a modified Foster-Meyer sediment model as the basis for the SED functional subroutine. It is sensitive to slope, depth of runoff, and indirectly, to crop cover. The Foster-Meyer sediment model is fully described in Section VII of this report.

EVAP is the evapotranspiration functional subroutine. It determines potential evapotranspiration for each time increment. Other related subroutines determine the actual water loss depending on the cloud cover, relative humidity, time of year, and ground cover. Moisture is extracted from the soil profile beginning at the top layer and continuing down through successive layers until a user specified depth is reached. The minimum moisture content in a given soil layer is never reduced below the minimum value in the tables of pressure head and diffusivity specified by the user.

EVAP is called when the rainfall rate is zero and the soil moisture content of the first soil layer (usually one centimeter) is below a user specified threshold (typically 0.3 to 0.4 centimeters, but the specified value depends on the soil type). As noted above EVAP and WATER are mutually exclusive.

Several input values are presently required by the EVAP functional subroutine. They are meteorological data, watershed latitude, and vegetation ground cover. The sole output requirement for the EVAP functional subroutine is the potential evapotranspiration available for each time increment.

EVAP is presently based on a modified Penman equation which is fully described in Section VII.

THE PESTICIDE CYCLE

The other major cycle within SCRAM's simulation structure is the pesticide cycle. This cycle introduces the pesticide into the simulation and accounts for all the physical processes involving the pesticide during the simulation. The present cycle includes an adsorption-desorption functional subroutine, a degradation functional subroutine, and a volatilization functional subroutine. The pesticide is introduced and dispersed in the soil profile by the adsorption-desorption functional subroutine. The degradation and volatilization functional subroutines remove pesticide from the soil profile. Figure 8 shows a simplified flowchart of the pesticide cycle.

The pesticide cycle is dependent on the water cycle for infiltration rate, water velocities in the soil profile, and the soil moisture profile for each watershed zone. Both cycles are called within the same simulation time increment (simultaneously).

ADDE is the adsorption-desorption functional subroutine. ADDE introduces the pesticide into the soil profile and moves the pesticide into the soil profile according to its adsorptive-desorptive properties. The pesticide concentration in solution and adsorbed is calculated for each soil layer and each watershed zone.

Introduction of the pesticide in the soil matrix occurs during simulation of the first rainfall event after pesticide application. The pesticide is moved vertically into the soil profile in the solution state in the direction of the net moisture flux. Once the pesticide is in a soil layer, adsorption occurs. The continual movement of moisture throughout the soil profile, due to infiltration, percolation, evaporation, and redistribution transports the solution phase of the pesticide while the continued

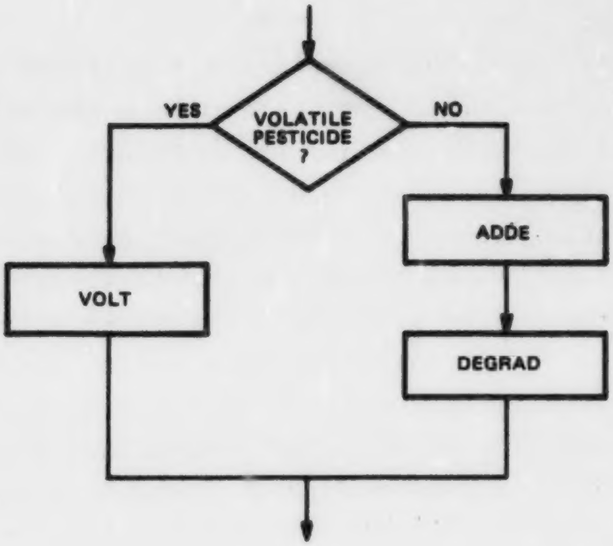


Figure 8. SCRAM pesticide cycle

adsorption-desorption process simultaneously occurs. The continuous relationship between the adsorbed state and the dissolved state is generally expressed as a Freundlich relationship.

Soil bulk density, soil water flux between soil layers, pesticide solubility, pesticide adsorption and desorption coefficients, a pesticide diffusion coefficient, and a pesticide conductively parameter must be available to ADDE. The WATER functional subroutine supplies soil water flux. The remaining parameters must be specified by the user.

At the present time ADDE is based on a dynamic adsorption-desorption model described by a one-dimensional differential equation. The adsorption-desorption processes are described by Freundlich equations. The fundamental equations are described in Section VII. Modifications were made to interface ADDE with WATER and account for the processes of evapotranspiration and pesticide degradation.

DEGRAD is the pesticide degradation subroutine. Its purpose is to account for the degradation of the pesticide in the soil profile. This degradation process has been shown to be dependent on soil moisture and soil temperature.

The input values required by DEGRAD are watershed parameters, soil properties, volumetric soil moisture content supplied by the WATER functional subroutine, and the soil temperature profile. The output required from DEGRAD is a multiplicative degradation factor to be used by BALANC, the bookkeeping subroutine, to degrade dissolved and adsorbed pesticide. An adequate DEGRAD functional subroutine should calculate a single multiplicative factor for the entire profile, whereas an ideal model should calculate depth dependent degradation factors corresponding to the depth dependent values of soil moisture and temperature.

DEGRAD is presently based on a first-order differential equation which describes subsurface pesticide degradation as a function of soil moisture and temperature.

VOLT is a specialized functional subroutine which is called only if the pesticide is known to be highly volatile. At the present time DEGRAD and ADDE are not called when VOLT is called. Two options are provided according to whether the pesticide diffusion coefficient is known or to be calculated from a linear regression equation based upon soil moisture, temperature, and bulk density.

VOLT requires input data on the pesticide application rate, initial pesticide distribution in the soil profile, soil bulk density, and the pesticide diffusion coefficient. If the diffusion coefficient is calculated, the WATER program supplies soil moisture profiles and the soil temperature profile is presently taken as constant.

VOLT is based upon solutions to the standard second order differential equation of diffusion (Fick's Second Law). Modifications and approximations were made to account for nonuniform incorporation of pesticide and interlayer diffusion. Details of the mathematical formulations are in Section VII.

SIMULATING LARGE WATERSHEDS

Approaches

SCRAM was originally designed to simulate pesticide transport on small watersheds of less than five hectares. However, during the second phase of the project, the simulation structure was drastically modified to provide greater flexibility and potential application to large water basins. The essential feature of the change is the introduction of watershed zones or subplots into the simulation structure to allow for areal variations in soil type, rainfall rate, and topography.

Two approaches were considered. The first was statistical and involved assigning probability distributions to the rainfall rate and infiltration capacity over the watershed area. The second approach associates unique combinations of soil properties, topography, and meteorological data with each zone. The first approach requires very little additional programming and minimal additional computer core storage. The second approach requires significant additional programming and large amounts of additional core storage. In addition, program execution time increases in proportion to the number of zones. In keeping with the basic SCRAM approach to avoid empirical and statistical models, the second approach was implemented.

WATERSHED ZONES

A maximum of 20 zones or subplots may be specified for a watershed. On small watersheds each subplot should have homogeneous soil properties and uniform topographic characteristics. Ordinarily the subplots all have the same rainfall rate and areal variation in rainfall is not required. The user is required to define the runoff relationship among the subplots, i.e., the distribution of runoff water from each subplot to adjacent subplots. Although primarily designed for simulating large watersheds, this procedure was used to simulate the runoff from the EPA/USDA watersheds (<3 hectares).

Expanding the subplot concept to a larger watershed, the user would divide the watershed into a maximum of 20 zones. Each zone would have a unique rainfall history, soil hydrologic properties, meteorology, and topography. As was the case for small watersheds the user defines the runoff relationship among the zones.

Even though the concept of zones has been introduced, some uniformity over the entire watershed is still required. The data needed for the total watershed is:

- Crop information

  a) crop type
  b) plant date
  c) maturity date
  d) harvest date

- Pesticide data

  a) pesticide properties
  b) application rate

    c) application method
    d) application date.

Data for each zone is permitted for:

- Rainfall history
- meteorology

    a) temperature
    b) relative humidity
    c) wind velocity
    d) cloud cover
    e) barometric pressure

- Soil parameters

    a) soil type
    b) hydraulic conductivity or diffusivity
    c) pressure head

- Average slope.

DATA REQUIREMENTS FOR WATER BASIN TESTING

In addition to the watershed zonal information specified above, a minimal experimental data set is required with:

- Measured runoff rate and volume for a single runoff event

- Measured sediment loss for the same runoff event

- Measured pesticide concentrations in the runoff and sediment.

Data for a complete growing season, rather than a single rain event, would be desirable.

Efforts to establish a suitable data base with which to test SCRAM included a literature search and attempts to acquire unpublished data.

The literature search failed to disclose a single data base possessing all the parameters required to test SCRAM.

In the search for unpublished data, inquiries were made to several offices of the United States Department of Agriculture, Agricultural Research Service. While portions of the required data were available, notably from the South Great Plains Watershed Laboratory in Chickasha, Oklahoma, a complete data set was unavailable. To realistically assess the water basin capabilities of SCRAM a complete data set is required. Simulation based on an incomplete data base would be costly without providing meaningful information.

SECTION VI
SIMULATION TESTING

INTRODUCTION

The testing of any complex simulation like SCRAM is a difficult process because of the interdependencies between submodels. For example, if the runoff is incorrectly predicted the sediment loss should also be incorrect. If both the sediment and runoff models are incorrect the error in predicting sediment loss may be compounded. Similarly, if the runoff is incorrect too much or too little water is infiltrated. The adsorption-desorption and degradation models depend on the amount of water infiltrated. Pesticide loss in the runoff and on the sediment depends on the runoff model, the sediment model, the adsorption-desorption model, and the degradation model. These relationships must be kept in mind when testing the simulation and interpreting the results.

Testing a simulation based upon deterministic submodels, which purport to describe the underlying physical processes, is somewhat different than testing a simulation designed around empirical or statistical models. The distinction lies in the way the simulation parameters are determined. Statistical and empirical model parameters are determined by "calibrating" the simulation against large masses of field experimental data. This procedure is somewhat akin to curve fitting and least squares analysis. As long as the number of parameters exceeds the number of variables by a sufficient margin, good results are reasonably assured.

SCRAM utilizes deterministic models based upon scientific principles. In theory, the model parameters can be determined independently, usually in a laboratory experiment, and then used in the simulation. Thus, the soil properties, pressure head and diffusivity, pesticide adsorption-desorption parameters, and the pesticide degradation parameters could be determined from laboratory experiments. For some models such as the sediment model this is not true. And of course the laboratory may be the field test site. If the simulation does not produce good results, the implication is that something is wrong with the appropriate underlying model rather than the simulation parameters. The first adjustments should be made to the model itself and only as a last resort should the parameters associated with the model be changed.

It was not possible to test SCRAM against all of the EPA/USDA field data as described in Section IV. Two watersheds, P-01 (2.70 hectares; non terraced, soybeans) and P-04 (1.38 hectares, terraced, corn) were selected for testing because of their relative sizes, locations, and crops. Diphenamid (P-01) and atrazine (P-04) were selected as test pesticides. Paraquat does not need to be simulated because it is strongly adsorbed on sediment and hence the sediment model determines the paraquat loss. A third pesticide, trifluralin, was used to test the volatilization model.

The results of the simulation tests are described in the remainder of this section. Runoff results (hydrographs) are presented first, followed by sediment loss, pesticide loss in the runoff and on the sediment, pesticide movement in the soil profile, pesticide degradation, and pesticide volatilization. The simulated results are compared to field measurements for the major runoff producing storms. However, the entire period from plant date through December 31, 1973, was simulated as a single four hour run on an IBM 370/145.

HYDROGRAPHS

In order to simulate the runoff from a small watershed using SCRAM, the user must specify the soil parameters by providing tables of moisture potential and diffusivity as a function of soil moisture content. Because of the approximations contained in the water model (e.g., soil depth increment, time step, boundary conditions), experimental values of moisture potential and diffusivity may not be an optimum choice. Selection of the parameters is also complicated by the requirement that the evapotranspiration model work properly if runoff is to be accurately predicted.

The predominate soil type in the area of the experimental watersheds is Cecil Sandy Loam, a typical Hapludult. However, based upon the results of the sensitivity analysis (Section VII), it was clear that the diffusivity and moisture potential data on Cecil Soils would not produce runoff for the storms recorded during 1973. Because of this and the limited availability of good hydrological data for a broad range of soil types, the initial simulation testing was accomplished using parameters for Light Clay (Section VII, Figures 65 and 66).

The hydrographs have been plotted against elapsed time rather than real time as recorded during the field measurements. Elapsed time is measured from the start of runoff. By plotting the hydrographs as a function of elapsed time differences which are due to clock asynchronization between the rainfall gauge and the hydrograph record are minimized. Also, differences between experimental and simulated hydrographs which are due to watershed characteristics which were not simulated are eliminated.

P-01 Hydrographs

The first storm of interest on P-01 occurred on the plant date, June 13, 1973. This storm is one of the most unusual storms recorded. Rainfall rates exceeded 0.2 cm/min; 1.6 cm of rain fell in the first 7 minutes of the storm. The rain stopped for 15 minutes during the storm, and a total of 1.9 cm was recorded in 26 minutes.

Simulated and actual hydrographs for June 13, 1973, are shown in Figure 9. The simulated hydrograph reflects a much faster response to the 1.6 cm of rainfall during the first 7 minutes of the storm. Most of the simulated runoff (335,297 liters) is caused by the fact that the rainfall rate exceeded the maximum infiltration rate permitted in the infiltration model. Measured runoff was 369,445 liters or 72% of the total rainfall, a surprisingly high figure in light of the recent tillage and dry soil conditions.

The second major storm on P-01 occurred on June 21, 1973. This storm was entirely different from that on June 13, 1973. Light rain for 8 minutes was followed two hours later by a twenty minute burst (1.4 cm), and then light rain for 10 minutes (0.1 cm).

The actual hydrograph shows a response only to the 20 minute peak rainfall, whereas the simulated hydrograph shows a response both to the rainfall peak and the light rainfall following the peak (Figure 10). The shape of the measured hydrograph compared to the measured hydrograph for June 13, 1973, illustrates the

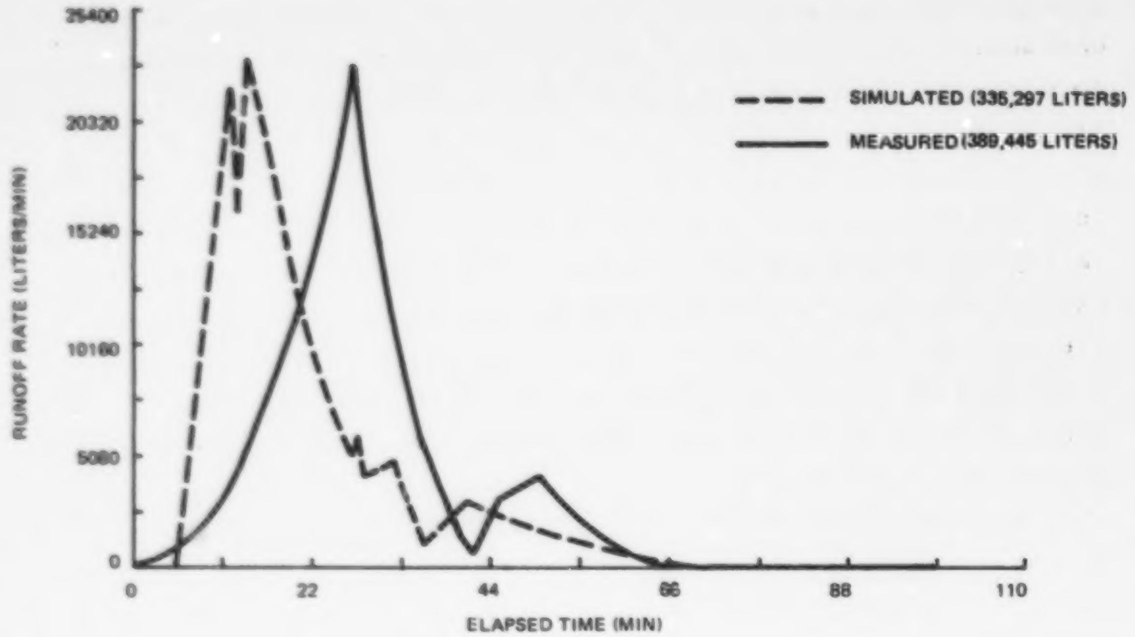


Figure 9. P-01 watershed: hydrograph for the June 13, 1973, storm

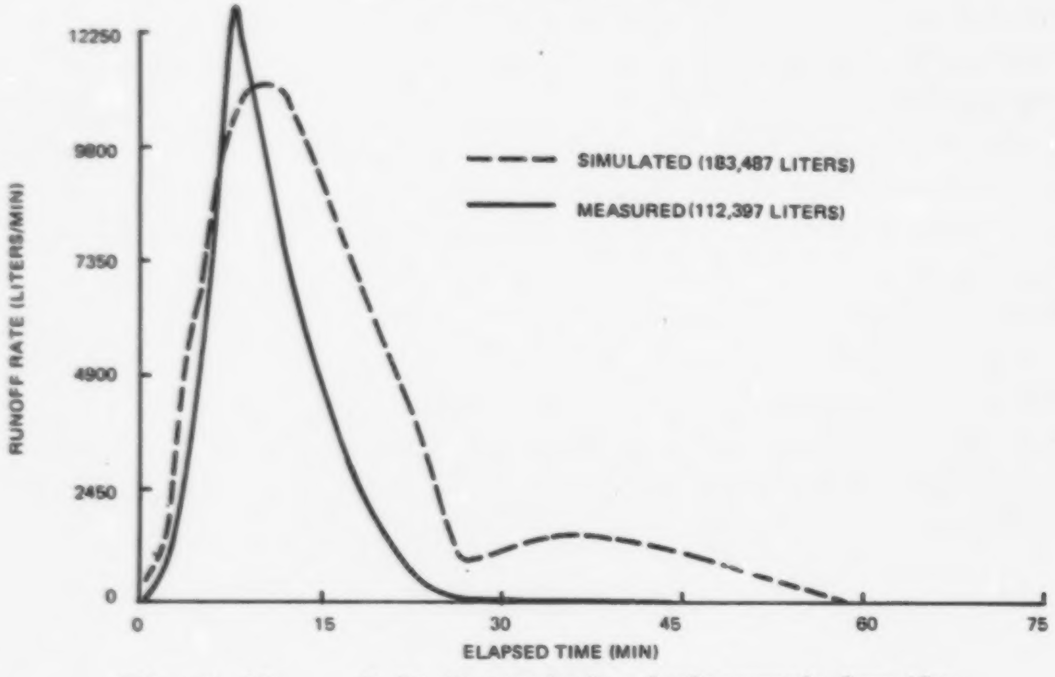


Figure 10. P-01 Watershed: hydrograph for the June 21, 1973, storm

initial changes that have occurred due to channelization and compaction. The six minute burst of rain on June 13 produced 40 minutes of runoff while the 20 minute peak rainfall period of June 21 produced runoff for less than 30 minutes. This effect is not simulated and the difference is not observed. Total measured runoff was 112,397 liters or 22% of the total rainfall. Expressed as a percentage of the 1.3 cm peak, 32% was observed as runoff. Simulated runoff was 183,487 liters (36%).

On July 8, 1973, 1.8 cm of rain fell over a period of 96 minutes. The rainfall rate decreases from the beginning of the storm (.05 cm/min) to the end of the storm (.007 cm/min). Hence, the high intensity rainfall of June 13, 1973, and June 21, 1973, is not present.

The actual hydrograph has two peaks of nearly equal magnitude, whereas the simulated hydrograph has a single peak of much smaller intensity (Figure 11). Actual runoff was 132,821 liters (27%) versus 32,938 liters (7%) simulated. Given the absence of two peaks in the rainfall record it is difficult to reconcile the measured hydrograph with the simulated hydrograph. Crop canopy may begin to impact on the form of the hydrograph at this time but the effect would be to eliminate peaks or smooth out the hydrograph. (The P-04 hydrograph for July 8, 1973, has two peaks, but the rainfall record also has two peaks.)

On July 30, 1973, a total of 2.8 cm of rain fell in 30 minutes. The actual hydrograph has an unusual flat top at the peak flow for 8 minutes. Total measured volume was 354,674 (47%) vs simulated volume of 457,400 (61%) (see Figure 12). At this point crop canopy may begin to reduce runoff volume, but the magnitude of the difference suggests that the soil type is not appropriate.

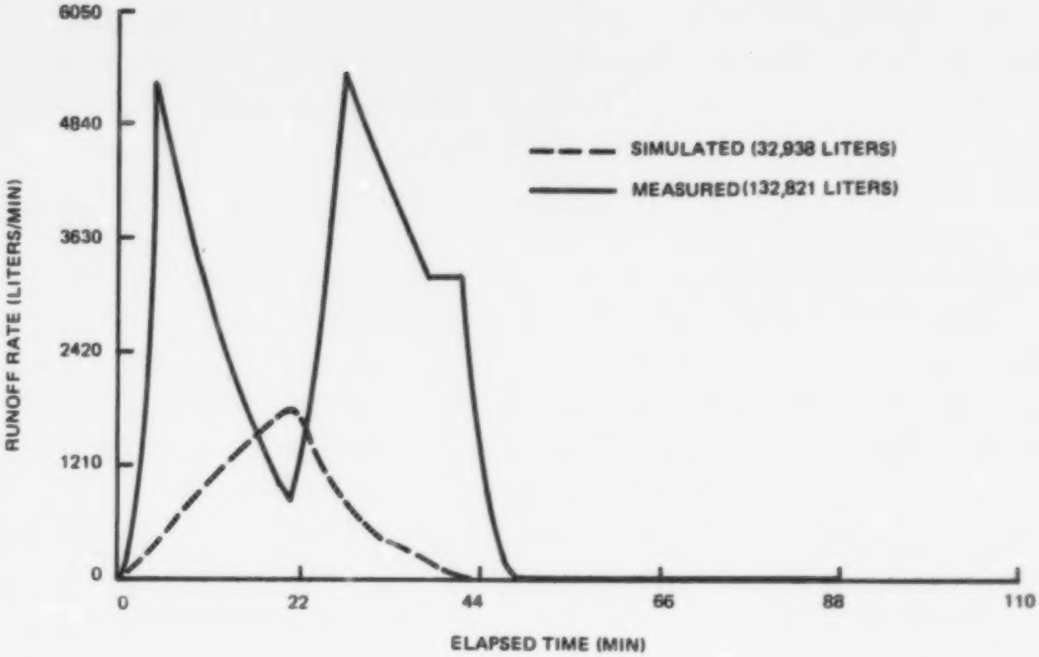


Figure 11. P-01 watershed: hydrograph for the July 8, 1973, storm

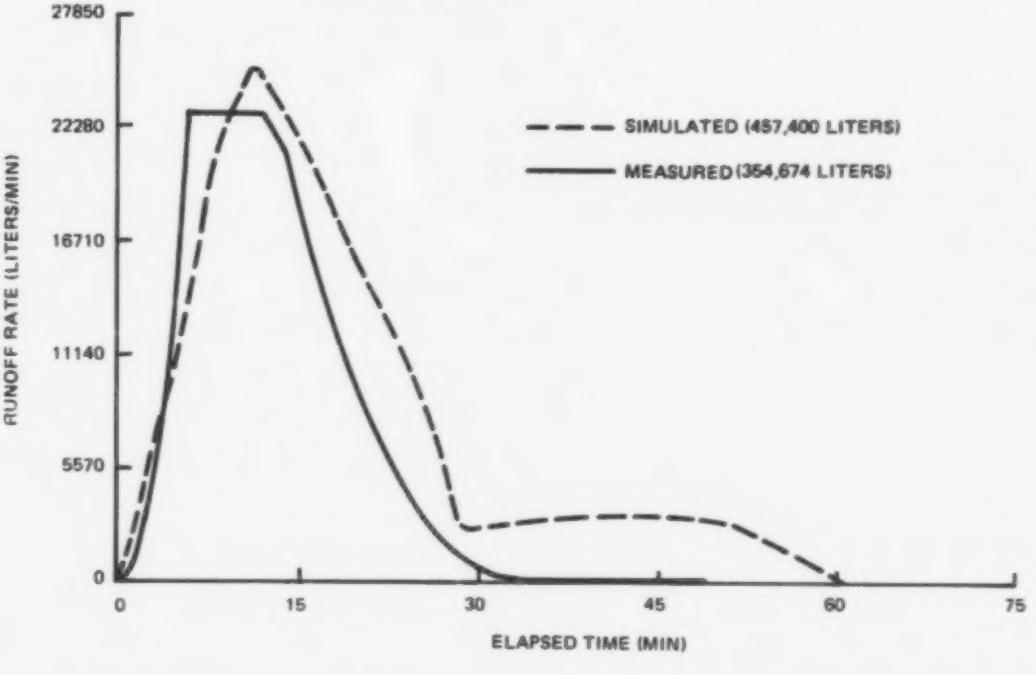


Figure 12. P-01 watershed: hydrograph for the July 30, 1973, storm

The next big storm did not occur until Sept 9, 1973, when 4.1 cm fell over a period of 91 minutes. Simulated runoff (641,508 liters, 58%) again exceeds the recorded volume (400,461 liters, 36%) as shown in Figure 13. Based upon the form of this hydrograph and previous ones, the soil parameters for clay do not provide sufficiently rapid percolation once the surface has saturated.

On Sept 13, 1973, 1.0 cm of rain fell over a period of 110 minutes, followed by 108 minutes without rainfall, and then 2.0 cm of rain fell over 39 minutes. The first 1.0 cm of rain did not produce any runoff. Both hydrographs have the same shape (Figure 14), but the simulated runoff of 286,226 liters (53%) exceeds the measured runoff of 224,742 liters (42%).

The largest discrepancy between simulated and observed runoff occurred for the storm on December 5, 1973, (Figure 15). Simulated runoff was 458,169 liters (42%) whereas measured runoff was only 21,360 (2%). Part of the difference is due to the small amount of rain that fell on December 4, 1973, late at night, which is not adequately handled in the present structure. However, at best this could only increase the runoff by 54,000 liters.

An examination of the rainfall rates does not produce an explanation. Rates in excess of 0.06 cm/min were observed during two periods (first two peaks in the simulated hydrograph) followed by a rate greater than 0.02 cm/min (third peak in simulated hydrograph). Rates less than these produced substantial runoff during other storms.

The final storm of the calendar year occurred on December 31, 1973. This storm came 14 hours after a storm on December 30, 1973, of 2.3 cm. Although the shape of the hydrographs (Figure 16) are in excellent agreement, the simulation using clay parameters predicts 657,600 liters (49%) of runoff whereas the measured runoff was 478,382 liters (36%).

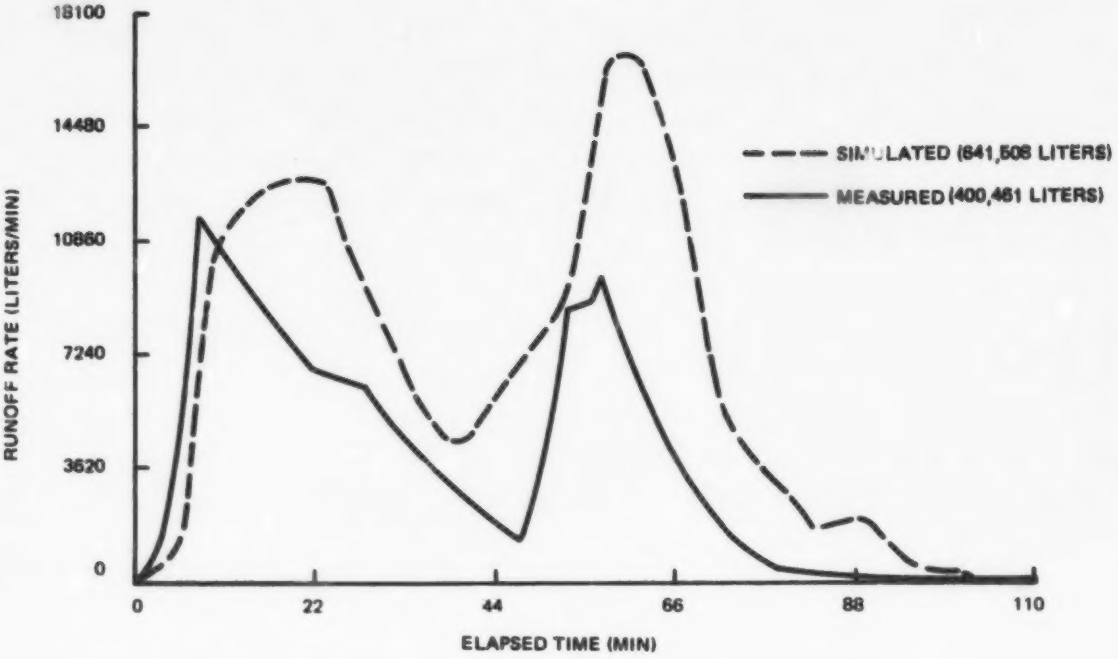


Figure 13. P-01 watershed: hydrograph for the September 9, 1973, storm

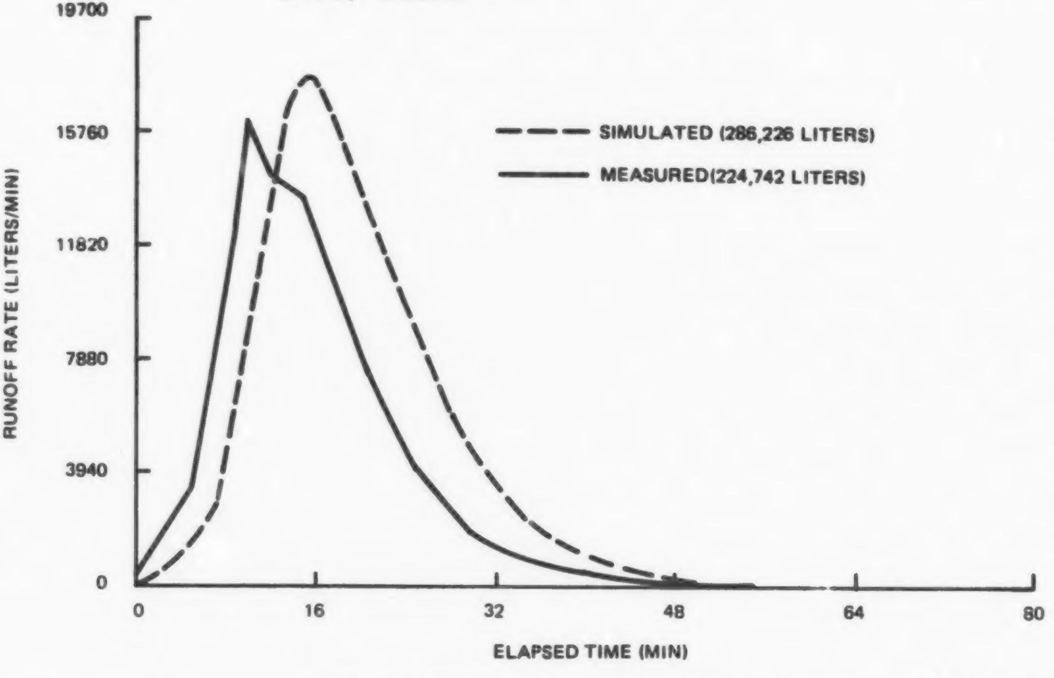


Figure 14. P-01 watershed: hydrograph for the September 13, 1973, storm

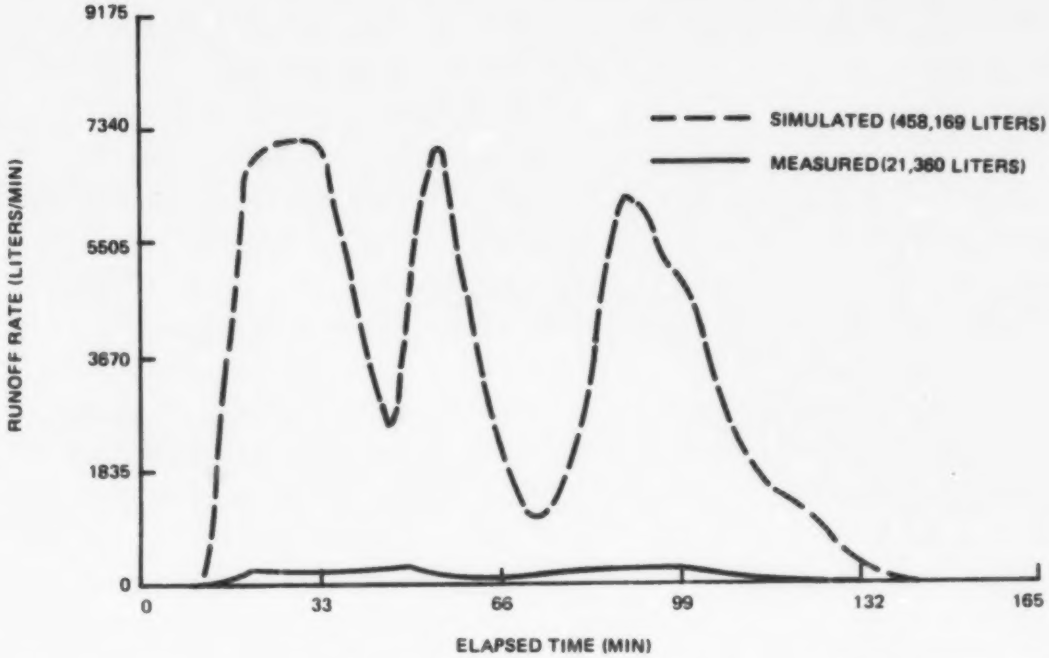


Figure 15. P-01 watershed: hydrograph for the December 5, 1973, storm

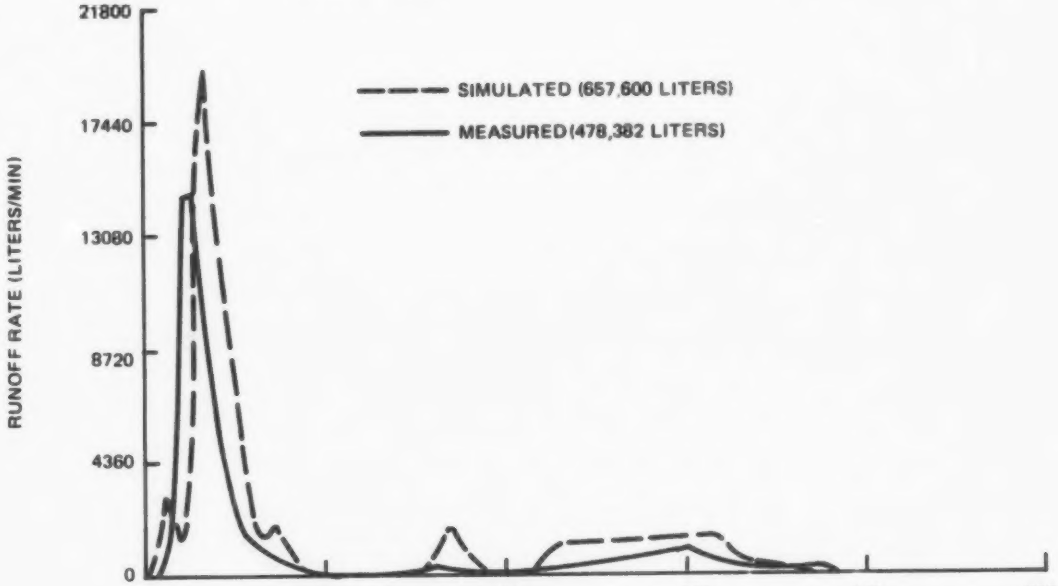


Figure 16. P-01 watershed: hydrograph for the December 31, 1973, storm

The four hour simulation run covering the period from June 13 through December 31, 1973, included a large number of smaller storms in addition to the eight major events discussed above. No particular pattern was evident from examining these storms. Most produced no runoff either simulated or measured. Some produced simulated runoff below measured. Total simulated runoff for the period June 13, 1973, through December 31, 1973, was 3,372,866 liters, whereas the recorded runoff was 2,179,497 liters.

The difference between total simulated runoff and recorded runoff could be eliminated by adjusting the soil parameters. However, the selection of total runoff as an optimization criterion is, at best, only appropriate for the infiltration model. For purposes of predicting the amount of pesticide washed off of P-01 for the season, it would be optimum to adjust the soil parameters to increase the runoff simulated for the June 13, 1973, storm. It would only be slightly more difficult to adjust the soil parameters to match the June 13, 1973, storm and improve the match between total simulated runoff and recorded runoff.

P-04 Hydrographs

In order to compensate for the overprediction of runoff on P-01 using moisture potential and diffusivity for Clay and for comparative purposes, soil types were changed before simulating the P-04 watershed. Essentially, hybrid soil was constructed by combining the moisture potential data for Clay with diffusivities for Geary Silt Loam. To simplify notation the hybrid is called SERL loam. Again, the necessity for the hybrid soil rather than Cecil Soil is apparent from the sensitivity analysis in Section VII of this report and from Figures 65 and 66 of that Section.

The first runoff producing storm after planting on P-04 occurred on May 23, 1973. It was a small storm of 1.2 cm, occurring over a period of 167 minutes. Simulated runoff was 6365 liters which exceeded the measured runoff of 2609 liters (Figure 17). This difference is not particularly significant because less than 2% of the rainfall was runoff.

On May 28, 1973, two large storms occurred on P-04. During the morning 4.8 cm fell over a period of 138 minutes. During late afternoon 4.3 cm fell over a period of 319 minutes. Simulated runoff shown in Figures 18 and 19 was below measured runoff for both storms. The shape of the simulated hydrograph for the morning storm is in excellent agreement with the measured hydrograph but does show a more pronounced response to the three peak rainfall periods. In the afternoon, the simulated hydrograph has three peaks whereas the measured hydrograph has four. However, the rainfall record for this storm reveals only three peaks and the fourth peak in the measured hydrograph is a mystery.

On June 6, 1973, 3.9 cm of rain fell over a period of 129 minutes. Simulated runoff was 241,810 liters vs measured runoff of 280,593 liters (Figure 20). The faster response to changes in the rainfall rate can again be seen in the simulated hydrograph. The spike at 44 minutes is reflected in the rainfall record but is not noticeable in the measured hydrograph.

The largest storm of the season occurred July 8, 1973, when 6.4 cm fell over a period of 231 minutes. This time the simulated runoff (464,050 liters) exceeded the measured runoff (411,185 liters). The sharp peaks in the simulated hydrograph shown in Figure 21 follow the sharp peaks in the rainfall record.

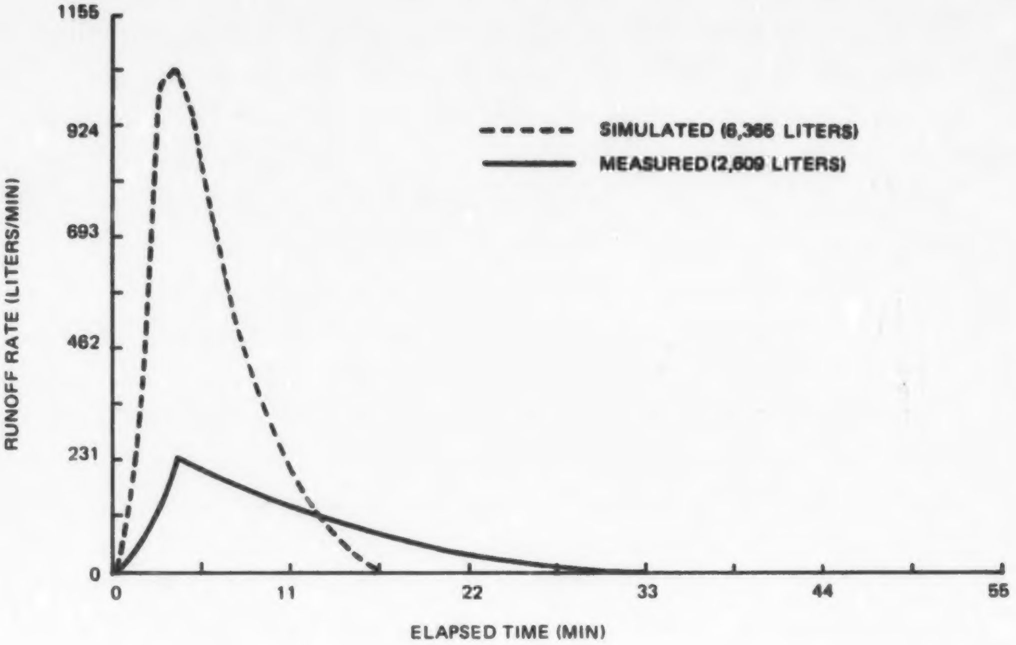


Figure 17. P-04 watershed: hydrograph for the May 23, 1973, storm

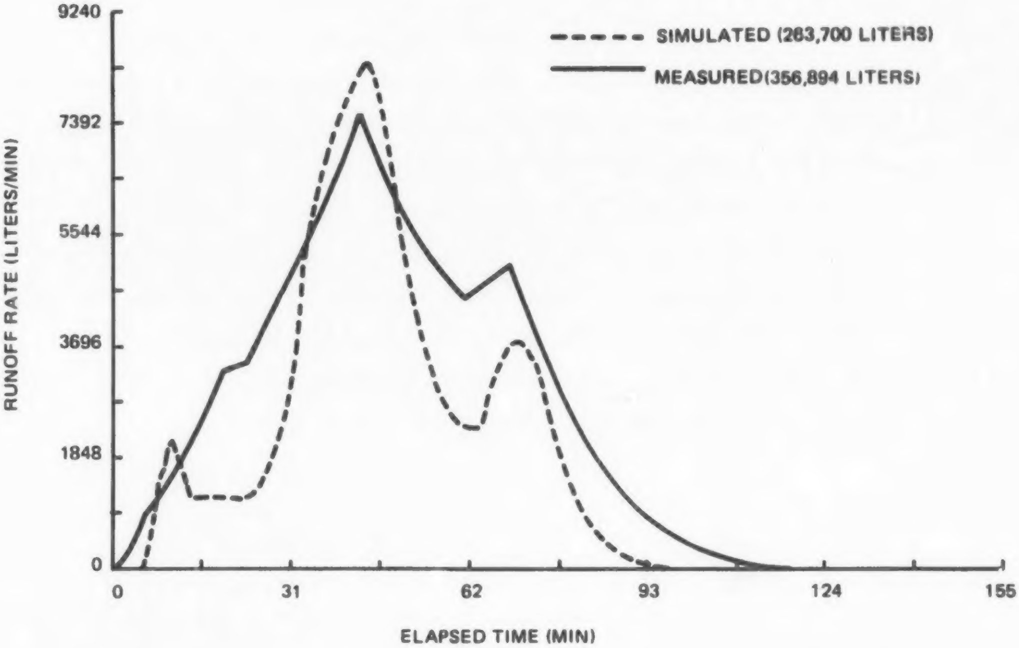


Figure 18. P-04 watershed: hydrograph for the May 28, 1973, storm

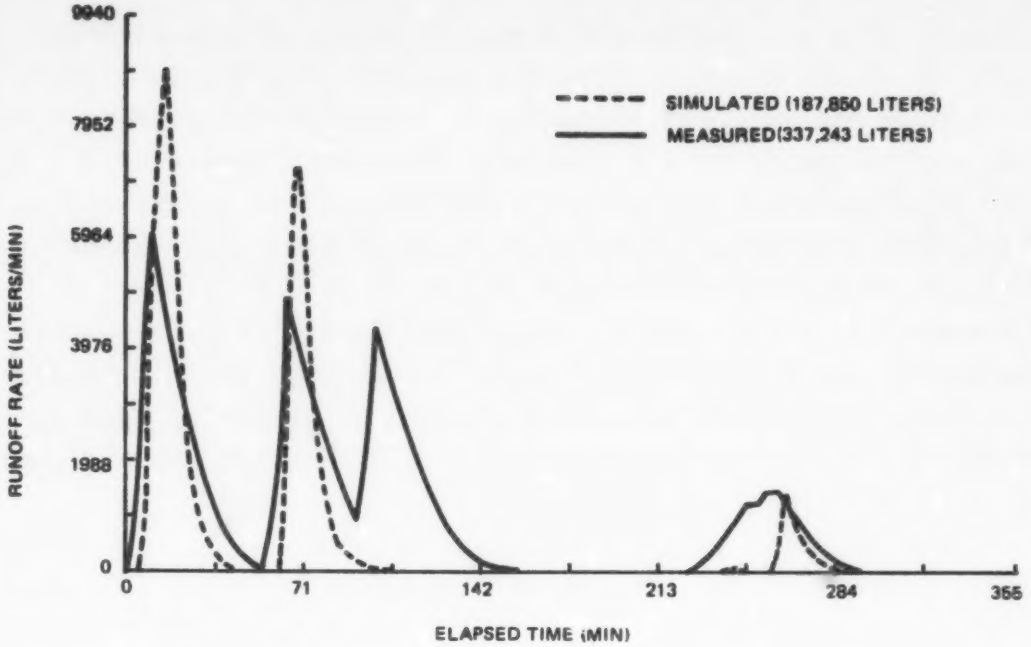


Figure 19. P-04 watershed: hydrograph for the May 28, 1973, storm (PM)

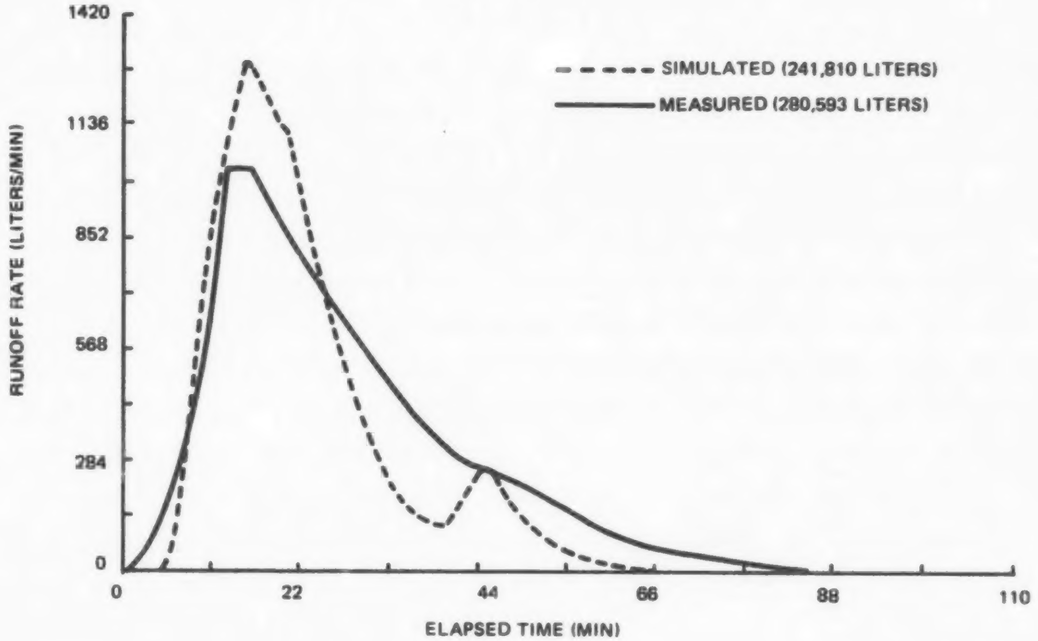


Figure 20. P-04 watershed: hydrograph for the June 6, 1973, storm

During July and August there were a number of small storms but most of them did not produce any runoff. Significant runoff does not occur again until September 9, 1973, when 4.4 cm fell on P-04 over a period of 108 minutes. Simulated runoff of 226,900 liters exceeded measured runoff of 163,449 liters and the simulated hydrograph shows a dramatic response to a 20 minute lull in the rainfall rate (Figure 22).

The best agreement between simulated runoff (130,700 liters) and measured runoff (132,777 liters) was recorded for the September 13, 1973, storm. Characteristically, the simulated hydrograph shows a sharp response to the burst of rainfall that occurred late in the storm (Figure 23).

Between September 13, 1973, and December 5, 1973, a number of small storms were recorded which did not produce any measured or simulated runoff. On December 5, 1973, 3.9 cm of rain fell over a period of 452 minutes, but most of the rain was concentrated in a 200 minute period. Simulated runoff (52,000 liters) exceeded measured runoff (11,016 liters) and the simulated hydrograph shows a sharp response to the three bursts of rainfall which were recorded (Figure 24). This storm was equally troublesome on P-01 and the results suggest that there is something unusual happening.

The final big storm of the year occurred on December 31, 1973, and extended into the morning hours of January 1, 1974. For approximately two hours it rained lightly, then for 38 minutes it rained at a moderate rate and then it drizzled for 9-1/2 hours. Simulated results do not agree with the measured results (Figure 25). The measured hydrograph shows runoff for the entire storm, whereas the simulated hydrograph does not show any runoff during the light drizzle. Rainfall rates of 0.004 cm/min recorded for this storm did not produce runoff during the summer and fall.

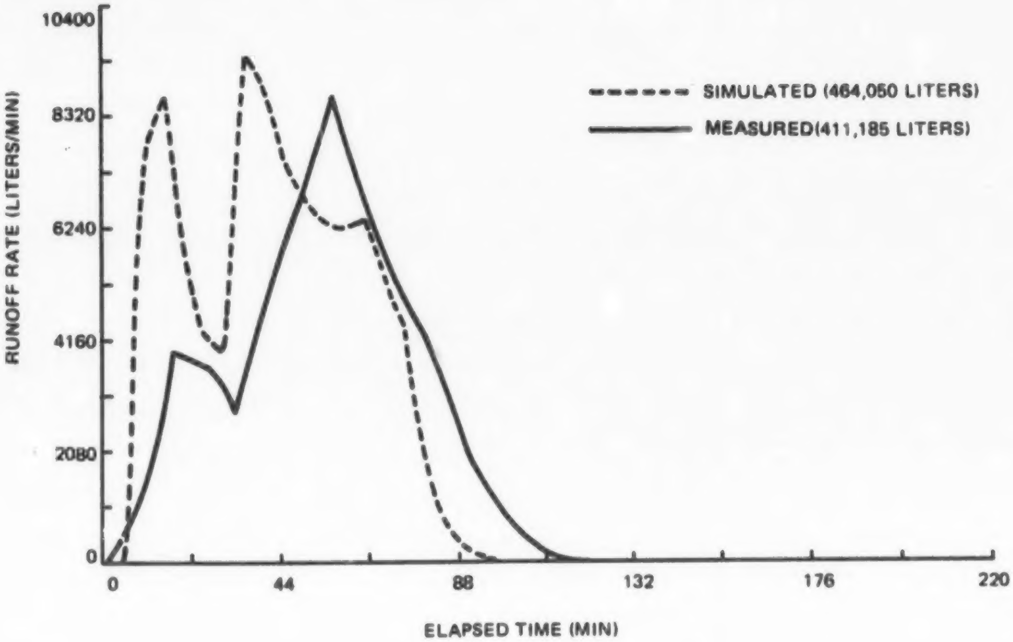


Figure 21. P-04 watershed: hydrograph for the August 7, 1973, storm

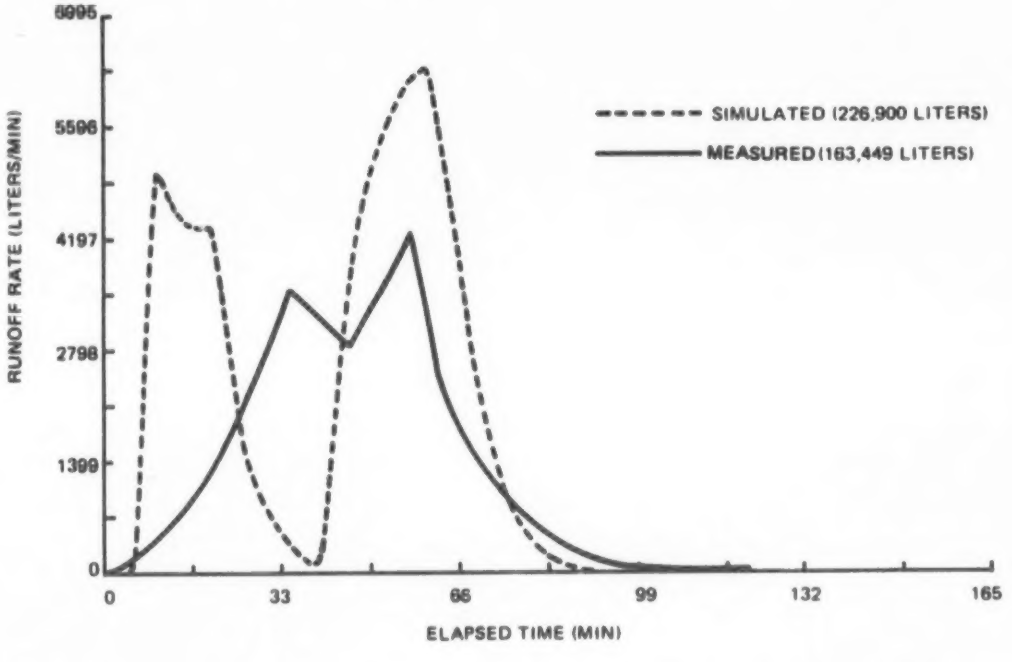


Figure 22. P-04 watershed: hydrograph for the September 9, 1973, storm

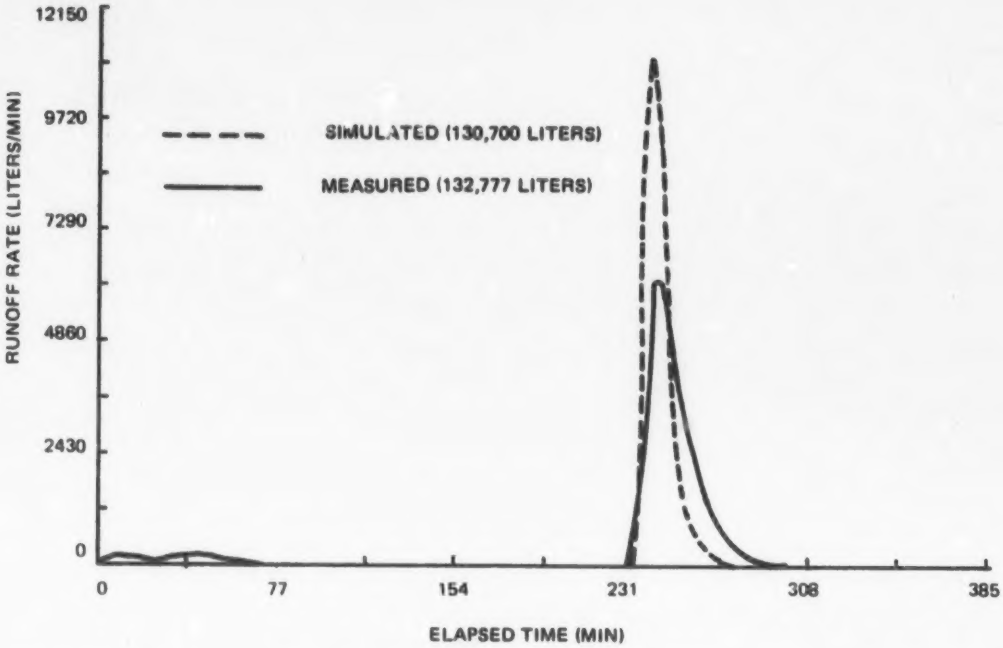


Figure 23. P-04 watershed: hydrograph for the September 14, 1973, storm

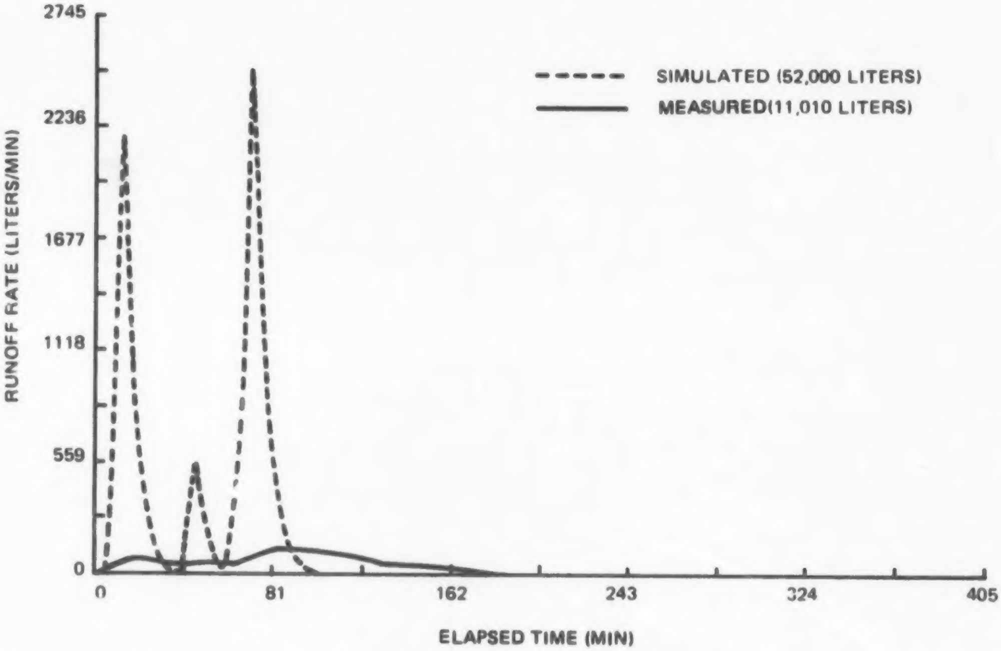


Figure 24. P-04 watershed: hydrograph for the December 5, 1973, storm

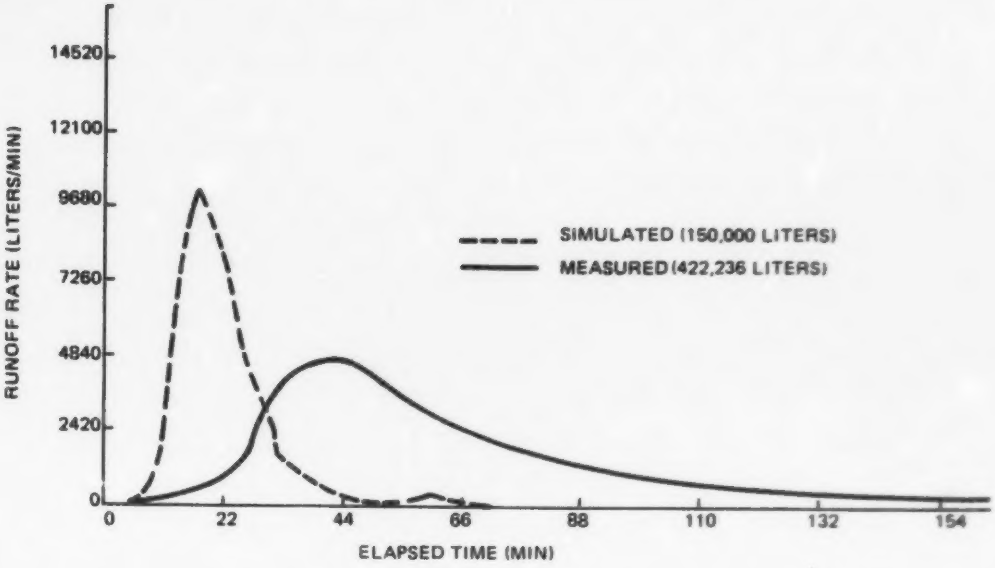


Figure 25. P-04 watershed: hydrograph for the December 31, 1973, storm

Total runoff for the period May 23, 1973, through the storm of December 31, 1973, was approximately 2,400,000 liters. Simulated runoff was approximately 1,900,000 liters. Thus simulated runoff is 79% of actual on P-04, using SERL loam and 155% of actual on P-01 using Clay parameters. By comparison the SERL loam parameters on P-01 produce 1,419,231 liters of runoff or 65% of actual.

Examination of the summary runoff figures shown in Tables 6 and 7 in the last part of this section does not reveal any clear trend. Simulated results tend to be low the first couple of months for both P-01 and P-04. Thereafter the simulated results are consistently high on P-01 and somewhat the same trend is seen on P-04. Simulated runoff on both P-01 and P-04 during December is in poor agreement with measured runoff. SERL loam on P-01 produced consistently low runoff except for the December 5, 1973, storm which was twice measured.

There are a number of possible explanations for the disagreement between simulated and measured runoff:

- Poor quality control on measured data
- Rain interception on crop canopy
- Evapotranspiration model is not working properly
- Improper specification of boundary conditions or depth increment within model
- Stochastic changes in the watershed - tillage, crusting, harvest - which are not simulated
- Nonuniform rainfall over the watershed
- Improper choice of soil type and/or improper specification of uniform soil type throughout the watershed.

Isolation and correction of the critical problems is a complex process which will require additional simulation, collection of data not presently available, and additional models for the simulation.

SEDIMENT

The Foster-Meyer (F/M) sediment model, which is described in detail in Section VII of this report, requires that the user specify three parameters denoted K_1, K_2, and K_3. K_1 is the transport capacity parameters, K_2 is the detachment capacity parameter, and K_3 is the rainfall detachment parameter. Because the F/M model has not been used extensively, K_1, K_2, and K_3 were set to give reasonably good results on the first storm. In general, it might not be a good idea to set the parameters for the first storm because of the unusual soil conditions that may exist at that time. However, most of the sediment and pesticide loss occurred during the first storm on P-01 and failure to set up the parameters properly would produce poor results.

Several problems developed during the initial tests of the F/M sediment model within SCRAM:

1. The structure of the watersheds, which were designed to enable the total runoff and sediment loss to be measured, was basically incompatible with the F/M model.

2. The F/M model does not allow for the effect of crop canopy on the kinetic energy of rainfall striking the ground.

3. The F/M model does not allow for the stabilization of the soil after plowing, planting, rainfall and of crop growth.

The first problem is largely unavoidable. The F/M model was designed for small rectangular plots with runoff along the lower edge of the plot, while the experimental watersheds are designed to empty through a flume. As a result, water and sediment are discharged into the flume from the upper portions of the watershed. Water backs up behind the flume and the natural flow off the watershed is lost. In addition, the total sediment which is dumped onto the flume approach exceeds the capacity of the flow and large amounts of sediment must be deposited.

Several modifications were made to the F/M model to account for the above problems. In making the changes the basic structure of the model was maintained, since many users may want to simulate watersheds without flumes.

A linear function was added to allow for crop canopy, which causes the value of K_3 to decrease from plant date to harvest. An exponent was then added which decreases the value of K_1 from plant date through six months, after which K_1 is constant. Finally, a limiting term (L) was added; L controls the ratio of the sediment load at the upper end of a subplot to the sediment load capacity of that plot at the lower end.

The limiting term L is necessary because the sediment transferred to the flume subplot may exceed the capacity of that subplot by orders of magnitude. When this occurs the F/M model will cause deposition, but on the flume subplot the rate of deposition may be too small to reduce the sediment load at the output to realistic levels.

P-01 Sediment Loss

In order for the sediment model to produce good results it is necessary to accurately simulate the watershed runoff. The F/M sediment model is not linearly dependent on the runoff volume and hence it is only possible to evaluate the sediment model for those storms which have simulated hydrographs nearly identical to the measured hydrographs.

The sediment loss for the eight major storms on P-01 between June 13, 1973, and December 31, 1973, are shown in Figures 26 through 33. These curves correspond to the hydrographs using clay soil parameters presented in the previous section.

One characteristic of the simulated sediment loss that is absent in the observed curves is the large increase in sediment concentration during the tail of the hydrograph. This result is not unexpected. After it stops raining the water which is backed up behind the flume is infiltrated rather rapidly. As a result the volume of water drops and the simulated concentration of sediment increases faster than the rate of deposition. This error is not particularly significant since the total volume of water remaining is generally small in comparison to the total volume of runoff. A similar effect can sometimes be seen as runoff begins.

Given the overprediction of runoff volume for most of the storms using clay parameters, the sediment model is working reasonably well. Simulated sediment loss for the June 13, 1973, storm was 14,456 kilograms versus a measured loss of 16,388 kilograms. Since the simulated runoff was below measured runoff, this is the expected result. Most of the other storms produce results which appear reasonable considering the form of the corresponding hydrograph. There are two storms which did not produce reasonable results; they occurred on July 30, 1973, and September 9, 1973.

The simulated sediment loss on July 30, 1973, was 21,468 kilograms (for 457,400 liters) whereas the measured loss was only 3975 kilograms (for 354,674 liters). Much of the difference is due to the 100,000 liters of excess simulated runoff over a

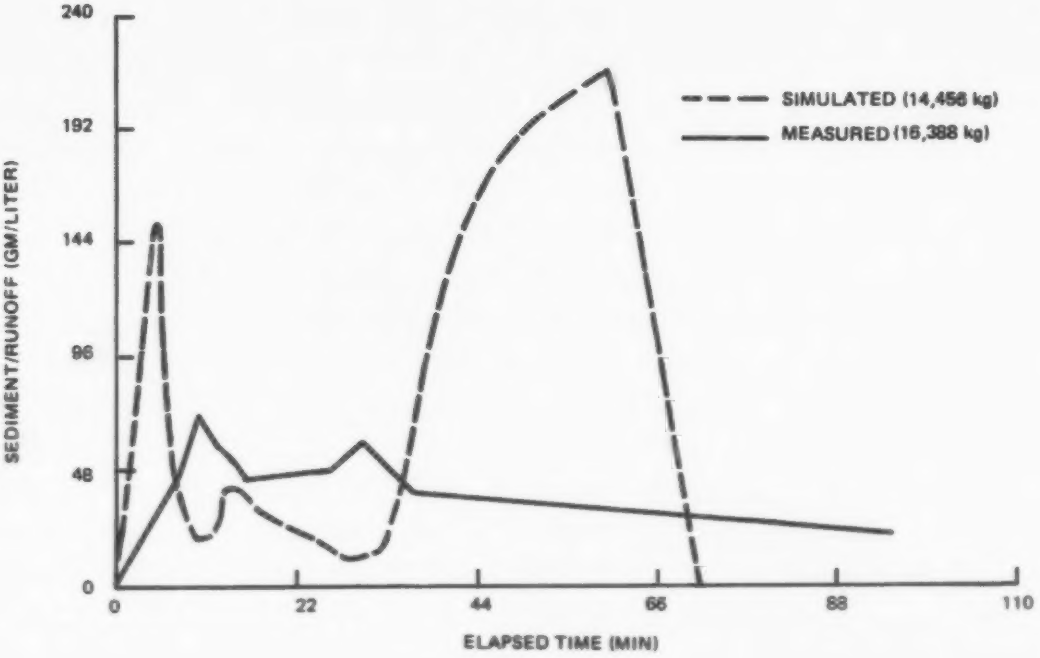


Figure 26. P-01 watershed: sediment loss for the June 13, 1973, storm

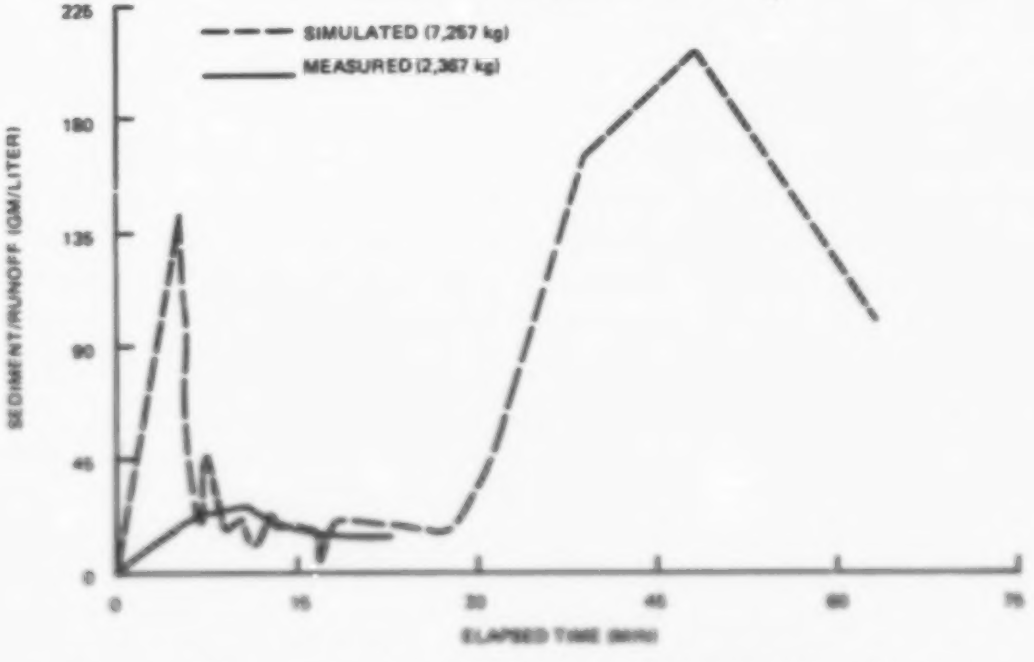


Figure 27. P-01 watershed: sediment loss for the June 21, 1973, storm

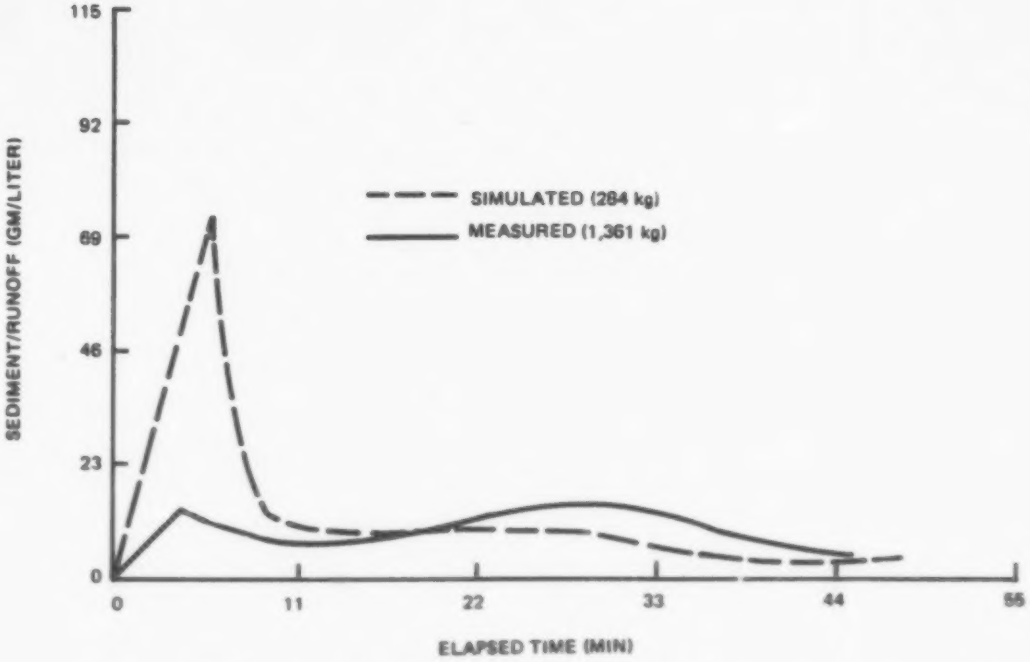


Figure 28. P-01 watershed: sediment loss for the July 8, 1973, storm

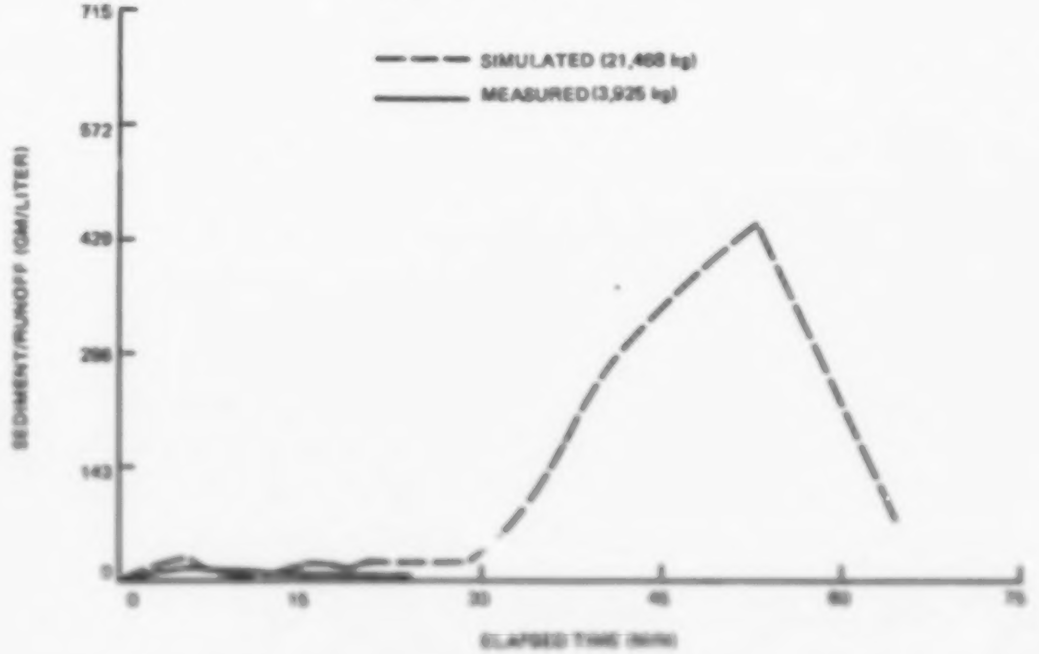


Figure 29. P-01 watershed: sediment loss for the July 30, 1973, storm

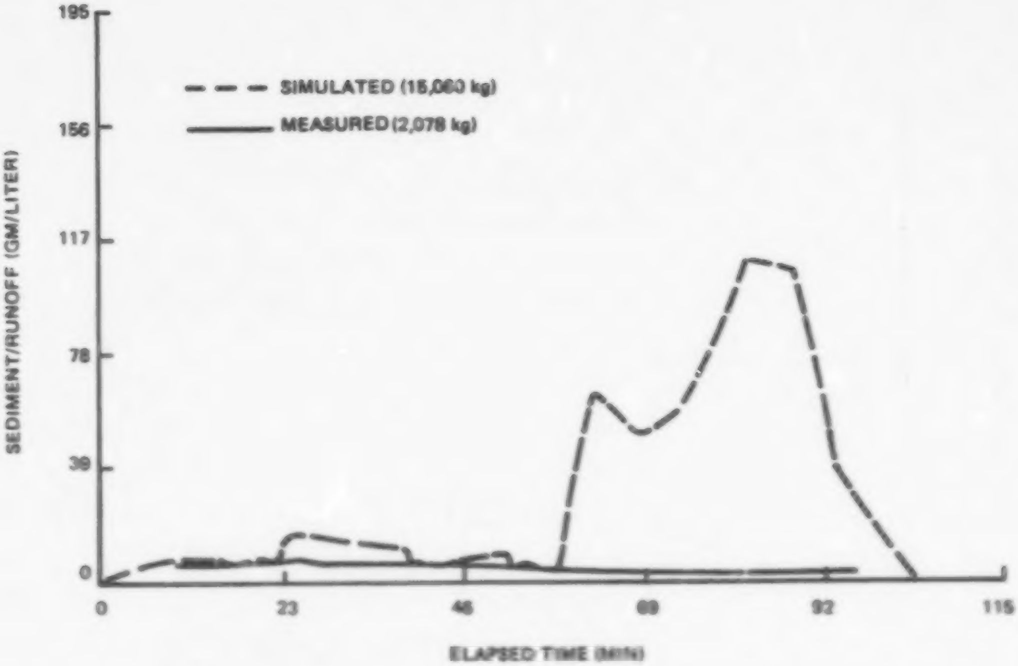


Figure 30. P-01 watershed: sediment loss for the September 9, 1973, storm

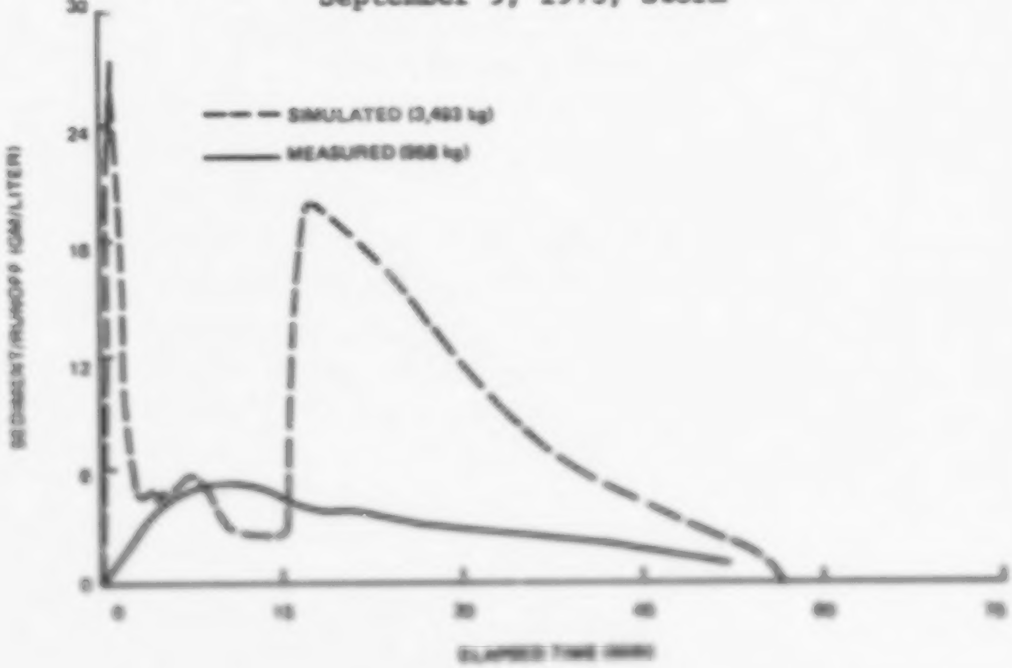


Figure 31. P-01 watershed: sediment loss for the September 13, 1973, storm

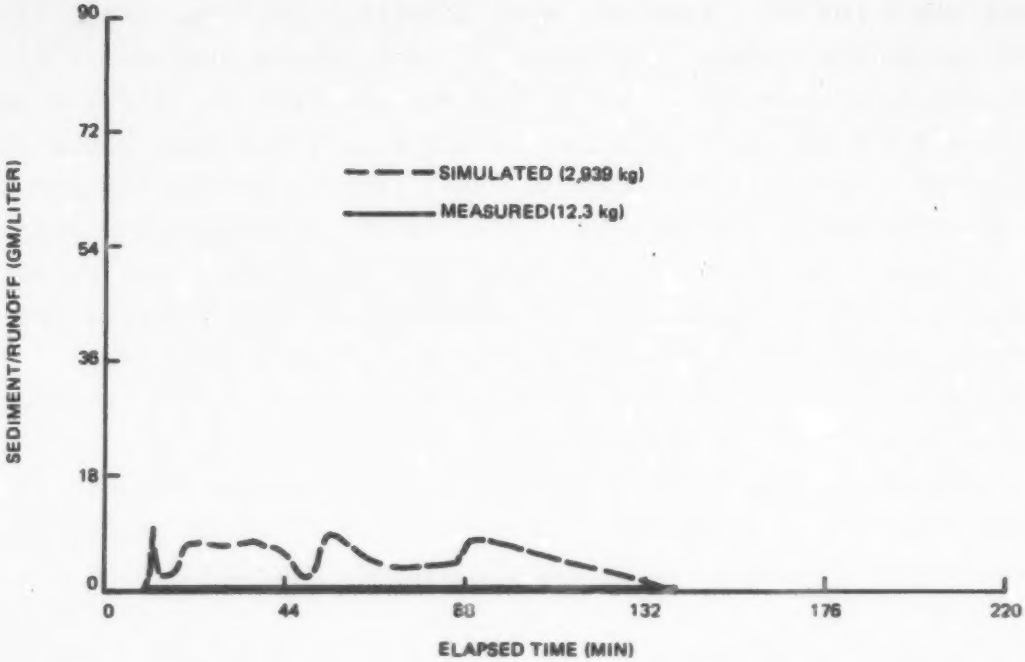


Figure 32. P-01 watershed: sediment loss for the December 5, 1973, storm

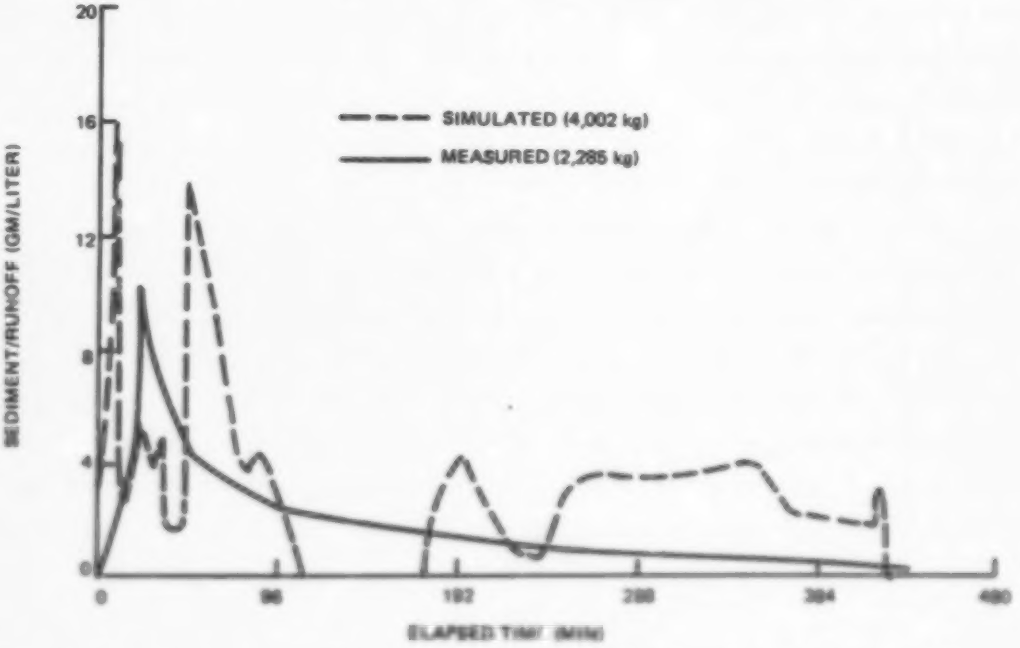


Figure 33. P-01 watershed: sediment loss for the December 31, 1973, storm

very short period. However, even allowing for this, the difference seems too large. The July 30, 1973, storm produced 2.79 cm of rain in 30 minutes. For comparison the June 13, 1973, storm produced 1.9 cm in 27 minutes. Total runoff was nearly the same for both storms but the July 30, 1973, runoff lasted for some 30 minutes while the June 13, 1973, runoff continued for almost 60 minutes. In addition, the July 30, 1973, hydrograph exhibits the novel "flat" top during the peak flow. Even allowing for stabilization of the watershed and crop canopy, the dramatic drop from 16,388 kilograms on June 13, 1973, to 3,925 kilograms on July 30, 1973, is a surprise.

The significance of runoff volume on sediment loss in the Foster-Meyer model was assessed by running the P-01 storm sequence with SERL loam hydrologic parameters. Simulated runoff was 65% of measured but the simulated sediment loss was 53% of measured. For the July 30, 1973, storm, simulated runoff dropped to 286,663 liters (81%) and the sediment loss dropped to 4,456 kilograms (114%). The change in simulated sediment loss from 21,468 kilograms to 4,456 kilograms indicates the sediment model may be working reasonably well. A similar result was observed for the September 9, 1973 storm where simulated runoff dropped to 368,933 liters (92%) and sediment loss dropped to 2,380 kilograms (115%).

These results demonstrate that the sediment model is highly sensitive to runoff volume. Adjustment of the sediment parameters can only be made after the runoff model is functioning properly. If the water model parameters are artificially adjusted to produce good results for total runoff, the sediment model will produce good results for total sediment loss. However, runoff and sediment loss for the first storm on P-01 would be grossly under-predicted under these conditions. Since almost all of the diphenamid loss occurred during the first storm it would not be possible to predict the seasonal loss of diphenamid.

P-04 Sediment Loss

The P-01 sediment parameters were not changed during the simulation of the P-04 storms from May through December 1973. Figures 34 through 39 illustrate the simulation results for the major storms. Without exception the simulated loss is below the measured loss. Although the runoff was generally low the simulated sediment loss is down by a factor of ten or more. The only other explanation for the dramatic difference between P-01 and P-04 is the difference in watershed geometries. P-01 is an unterraced watershed of 2.7 hectares with an average slope of 4% whereas P-04 is terraced, 1.25 hectares with an average slope of 2% toward the drainage channels. The difference in runoff volume can account for a factor of five as was seen by the results for P-01 using SERL loam. The remaining difference is due to the nonlinear dependence of the sediment model on slope.

PESTICIDE LOSS VIA RUNOFF AND EROSION

The simulation of pesticide loss in the runoff and on the sediment is dependent on accurately predicting runoff, sediment loss, the proper adsorption-desorption rates, and degradation rates for the entire growing season. It is especially critical for the storms immediately following the pesticide application when pesticide loss is highest. Thus, evaluation of pesticide loss predictions can only be performed by properly considering the total system involved.

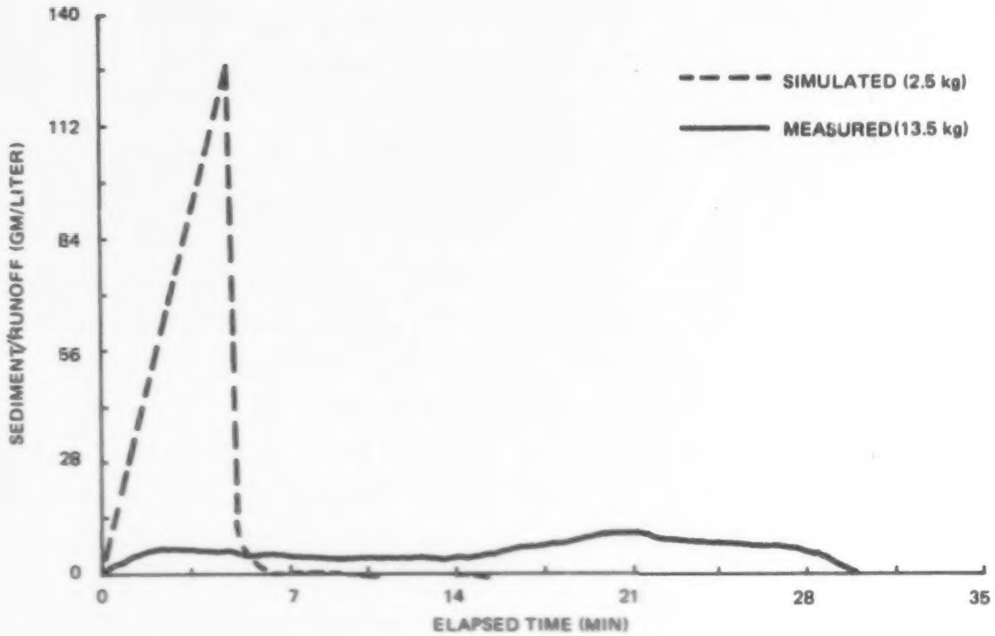


Figure 34. P-04 watershed: seliment loss for the May 23, 1973, storm

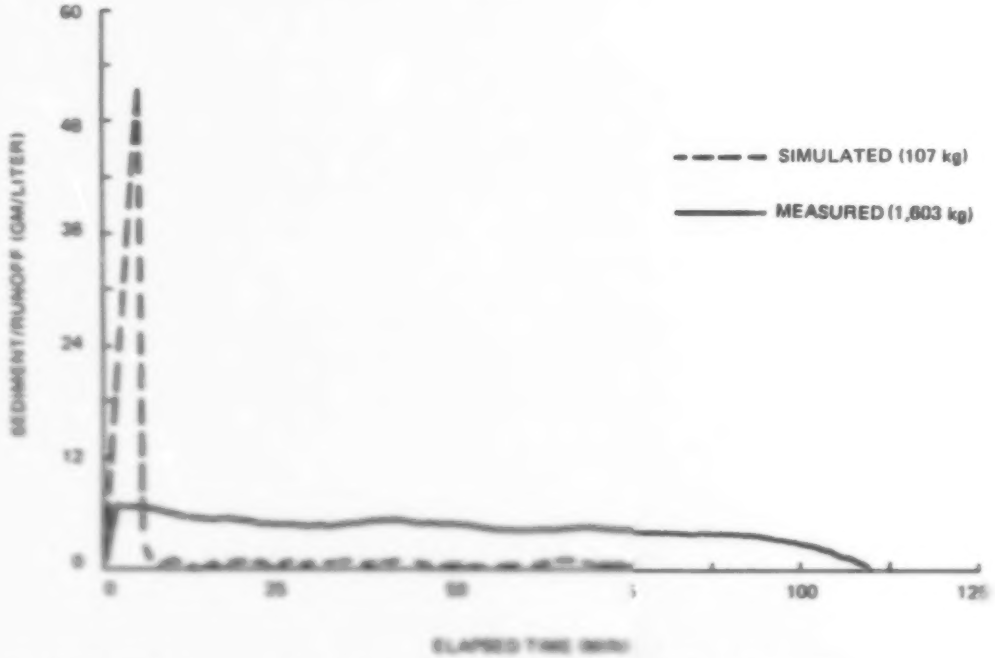


Figure 35. P-04 watershed: sedment loss for the May 28, 1973, storm

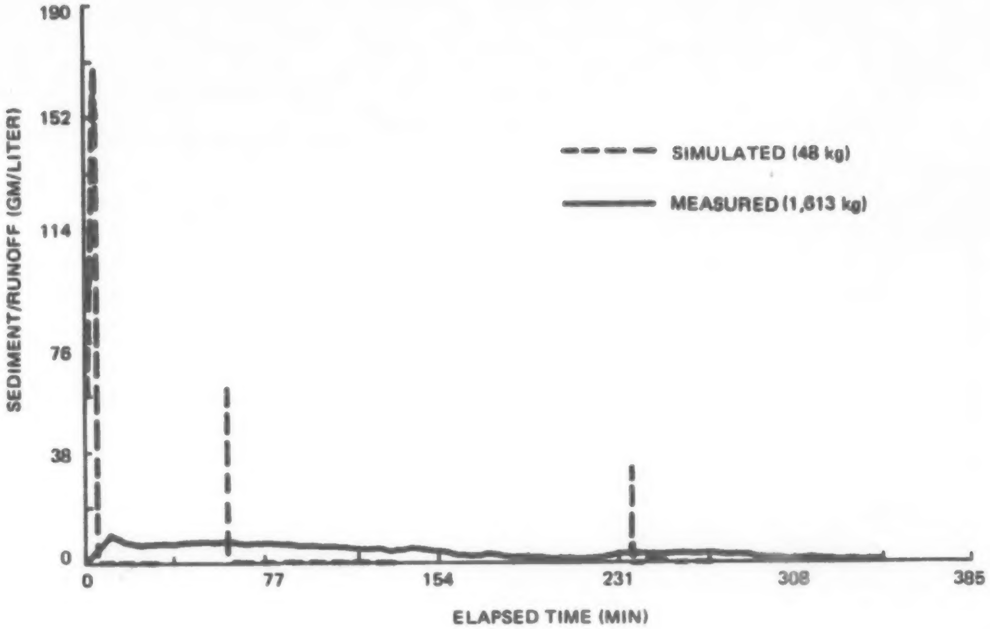


Figure 36. P-04 watershed: sediment loss for the May 28, 1973, storm

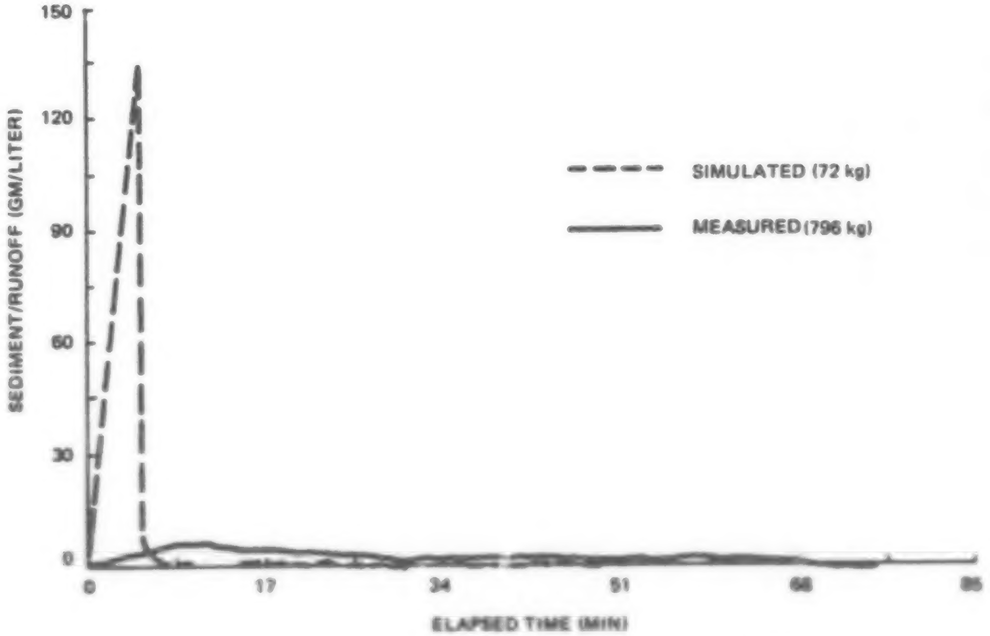


Figure 37. P-04 watershed: sediment loss for the June 6, 1973, storm

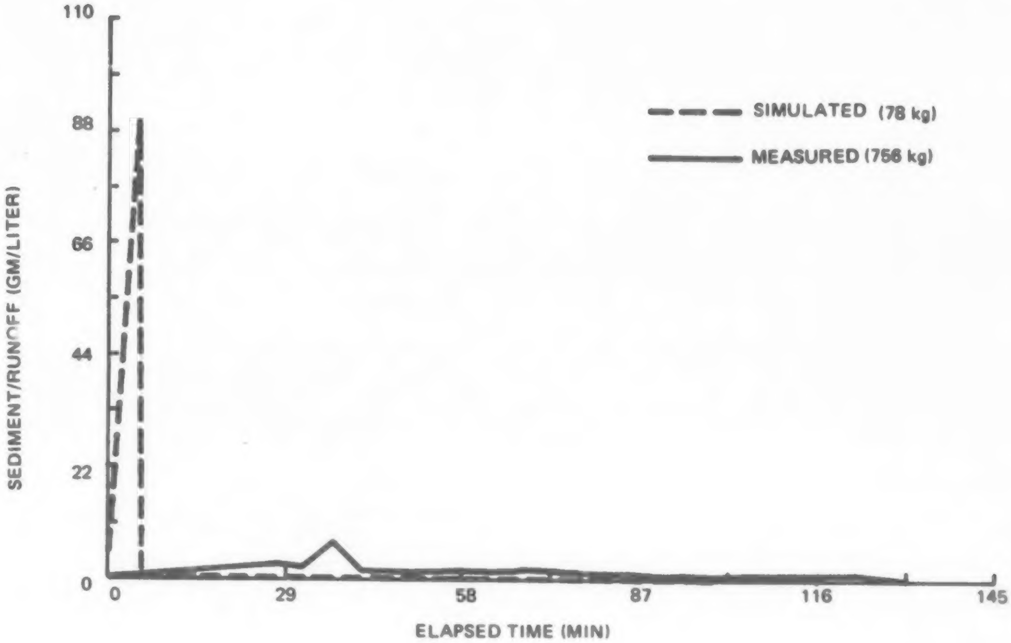


Figure 38. P-04 watershed: sediment loss for the July 8, 1973, storm

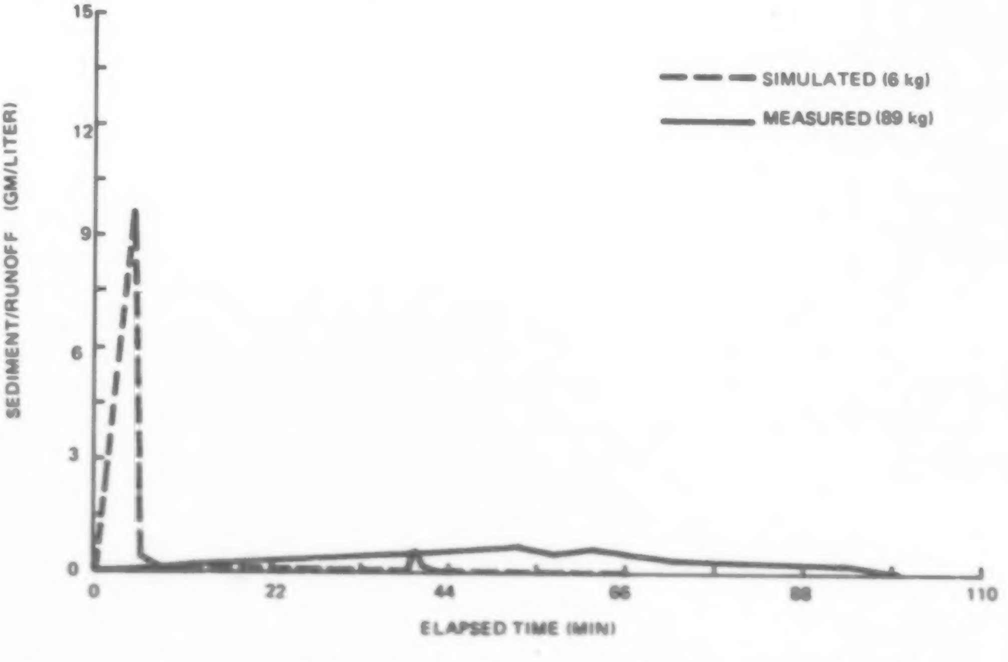


Figure 39. P-04 watershed: sediment loss for the September 9, 1973, storm

At the present time a deterministic model to describe the mass transfer of pesticide from the zone of erodibility, i.e., across the boundary separating the moving runoff film and soil surface has been conceptualized but not developed.

Four mechanisms are potentially involved:[13] (1) diffusion plus turbulent transport of dissolved pesticide from the soil interstices, (2) pesticide desorption from sediment particles, (3) dissolution of crystalline pesticide at the boundary, and (4) dissolution of crystalline pesticide carried with the sediment.

In the absence of an available deterministic model, a simple empirical approach has been utilized in SCRAM. Turbulent transport is assumed to be related to the depth of runoff on a subplot. Due to the formation of rills and the soil surface dynamics, runoff is assumed to interact with the dissolved pesticide in the soil intertices to a depth of two centimeters. The surface area of runoff interactions is assumed to decrease exponential from plant date to harvest.

Mathematically, the pesticide mass transfer to the runoff water is expressed as:

$$\text{Loss }(H_2O) = [RO \cdot 2.2 \cdot 10^{-4} \cdot \bar{C} \cdot e^{-(MO)}] \qquad (1)$$

where $\text{Loss }(H_2O)$ = grams loss in the runoff

RO = runoff volume (ℓ)

$2.2 \cdot 10^{-4}$ = proportionality factor

$\overline{C}$ = average micrograms of pesticide in solution in the top two layers

$e^{-(MO)}$ = factor accounting for the crusting and formation of rills thereby reducing surface area affected by runoff

MO = months since plant date

Pesticide Loss in the Runoff

Diphenamid was applied on P-01 on June 13, 1973. Figure 40 shows the simulated rate of pesticide loss in the runoff for June 13, 1973, storm compared to the measured values. A loss of 608 grams was measured. The general shape of the graphs indicates that the predicted rate of diphenamid loss does not significantly deviate from the loss actually observed.

Figures 41 and 42 show similar graphs of diphenamid loss in the runoffs on June 21, 1973, and July 8, 1973, with measured losses of 27.6 grams and 1.77 grams, respectively. The model overpredicts in the amount of diphenamid loss in the runoff on June 21, 1973, (133 grams) and on July 8, 1973, (4.16 grams).

On July 21, 1973, however, WATER overpredicts the amount of runoff and DEGRAD leaves more diphenamid in the soil profile than was measured, causing the high loss predicted. On July 8, 1973, WATER underpredicts the volume of runoff but DEGRAD still leaves more diphenamid in the soil profile than was measured. Hence, SCRAM still overpredicts the diphenamid loss in the runoff but not by as large a margin. Simulated and measured losses of diphenamid during the period from July 8, 1973, through September 9, 1973 were not significant.

Figures 43 through 45 show the atrazine loss in the runoff for the May 28, 1973 (AM), May 28, 1973 (PM), and June 6, 1973, storms. SCRAM predicted losses of 87, 44, and 9 grams respectively, whereas measured losses were 17, 14, and 3 grams.

Most of the difference in the totals can be attributed to the degradation model. On May 28, 1973, approximately 90 percent of the atrazine was degraded, whereas simulated degradation was 53 percent. Similarly, by June 6, 1973, 93% was degraded, whereas simulated degradation was 75%.

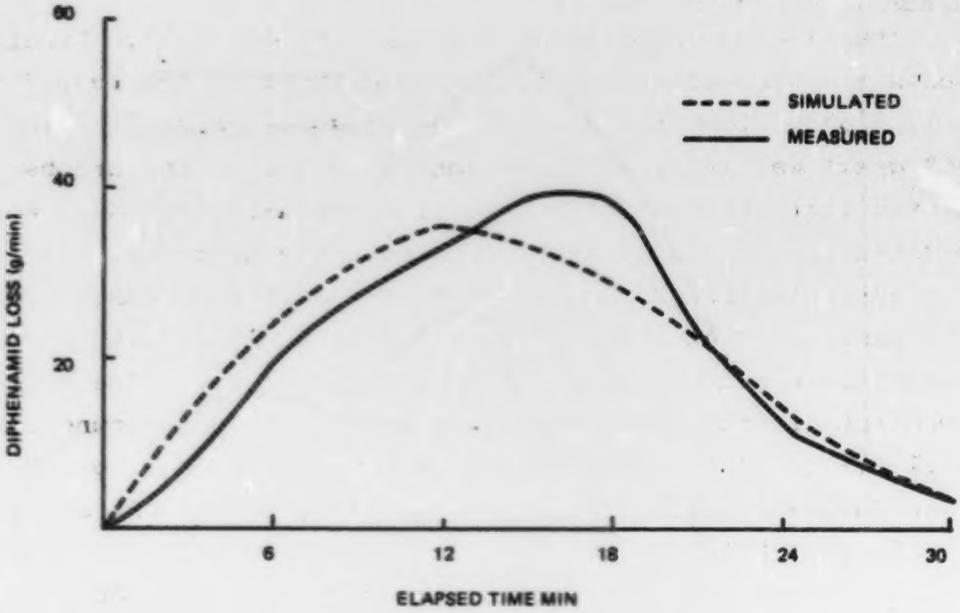


Figure 40. P-01 watershed: rate of diphenamid loss in runoff for the June 13, 1973, storm

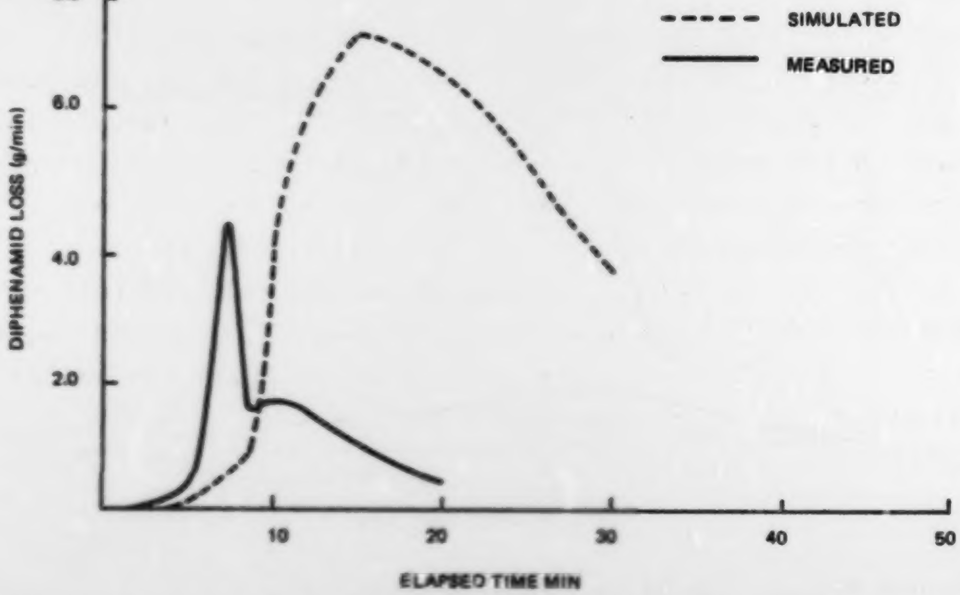


Figure 41. P-01 watershed: rate of diphenamid loss in runoff for the June 21, 1973, storm

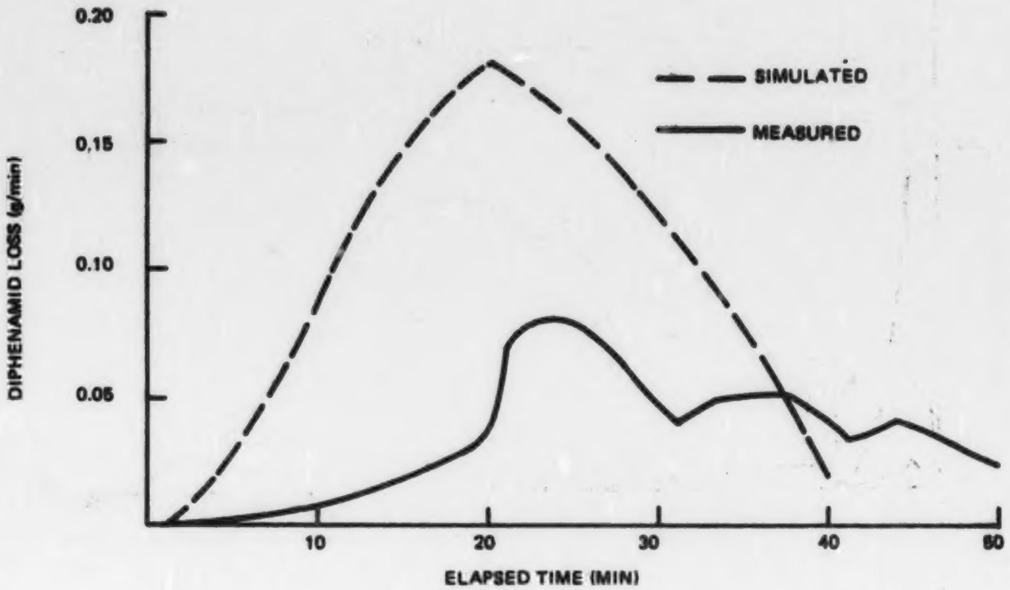


Figure 42. P-01 watershed: rate of diphenamid loss in runoff for the July 8, 1973, storm

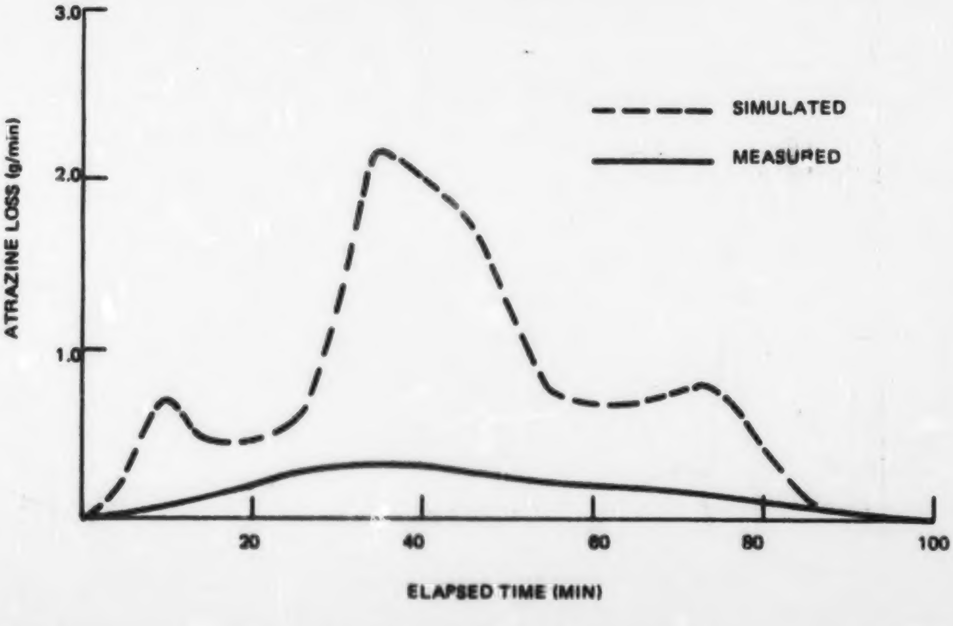


Figure 43. P-04 watershed: rate of atrazine loss in runoff for the May 28, 1973, storm (AM)

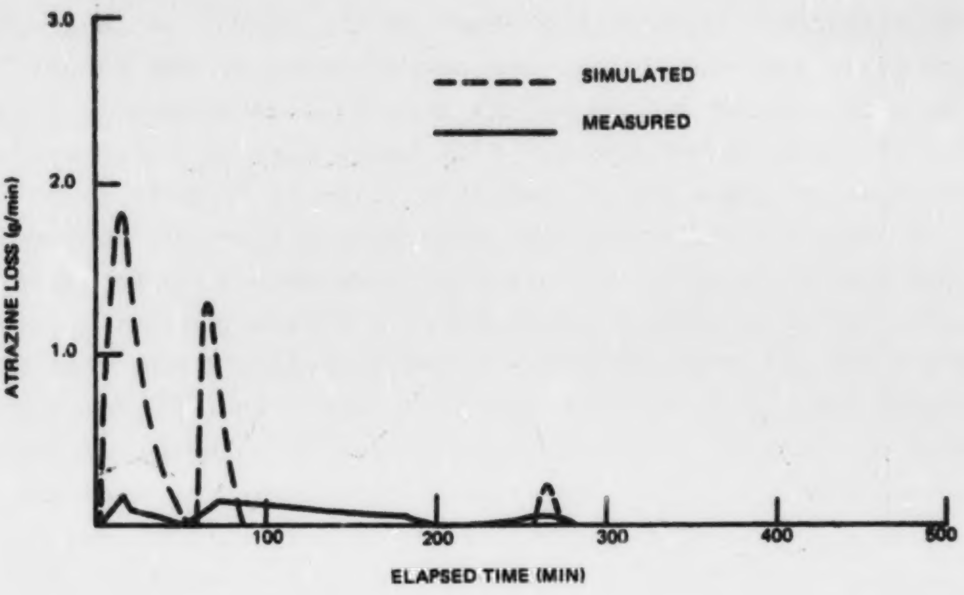


Figure 44. P-04 watershed: rate of atrazine loss in runoff for the May 28, 1973, storm (PM)

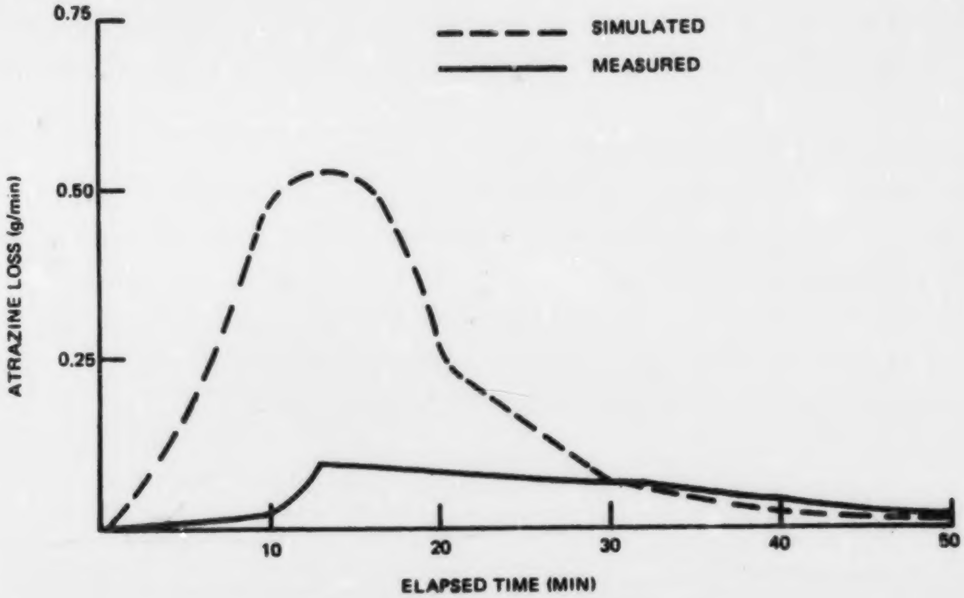


Figure 45. P-04 watershed: rate of atrazine loss in runoff for the June 6, 1973, storm

The difference between the shape of the curves is unexpected. Simulated atrazine losses are proportional to the runoff depth on each subplot and hence the rate of loss increases during peak runoff. The measured rate of atrazine loss is relatively flat and does not show any significant response to peak runoff flows. Since P-01 pesticide loss does show a response to runoff rate, the change is probably related to the watershed topography, crop type, and conservation practices. P-01 was planted in soybeans, was not terraced, and had an average slope twice that of P-04, which was terraced and planted in corn. Runoff from P-04 will tend to interact with the soil surface to a lesser degree than runoff does on P-01. Once runoff flow begins on P-04 the interaction with the soil may not change significantly even though the average runoff depth increases. This would produce a constant rate of atrazine loss.

Measured losses of atrazine in the runoff were insignificant after June 6, 1973, because degradation was nearly complete. Simulated losses were not significant because of degradation and the simulated movement of atrazine into the soil profile which rapidly depleted atrazine concentrations in the top soil levels.

Pesticide Loss on the Sediment

The amount of pesticide transported on the sediment will depend on: (1) the origin of the sediment due to areal variation in pesticide application (2) desorption of pesticide from the sediment during runoff, (3) adsorption due to dissolution of crystalline pesticide, and (4) the depth of the interaction zone between runoff water and the soil profile.

In the absence of a developed deterministic model an empirical model is presently included in SCRAM. For each subplot the concentration of pesticide on the sediment is assumed to be proportional to the sediment load, the concentration of absorbed pesticide in the upper two centimeters, and the elapsed time since plant date. Mathematically:

$$\text{Loss (SED)} = [\text{SED} \cdot 0.08 \cdot \bar{S} \cdot e^{-(\text{MO})}] \tag{2}$$

where Loss (SED) = grams of pesticide loss on sediment
SED = grams of sediment loss
0.08 = proportionality factor
$\bar{S}$ = average micrograms of adsorbed pesticide in the top two layers
$e^{-(\text{MO})}$ = factor accounting for the crusting and formation of rills thereby reducing the surface interaction area
MO = months since plant date.

Figures 46 and 47 show the simulated and measured diphenamid sediment concentrations on P-01 for the June 13, 1973, and June 21, 1973, storms. Although the simulated curves do not have the same shape as the measured curves, the total simulated losses (8.8 and 2.8 grams) compare favorably with the measured losses of 10.5 and 1.6 grams. Simulated and measured losses on the sediment were not significant after June 21, 1973 (<7%).

Simulated losses of atrazine on the sediment exhibit the same behavior as diphenamid on P-01. However, the simulated sediment loss is less than 10% of the measured loss, hence simulated atrazine loss on the sediment is not significant. Accordingly, the corresponding graphs are not shown.

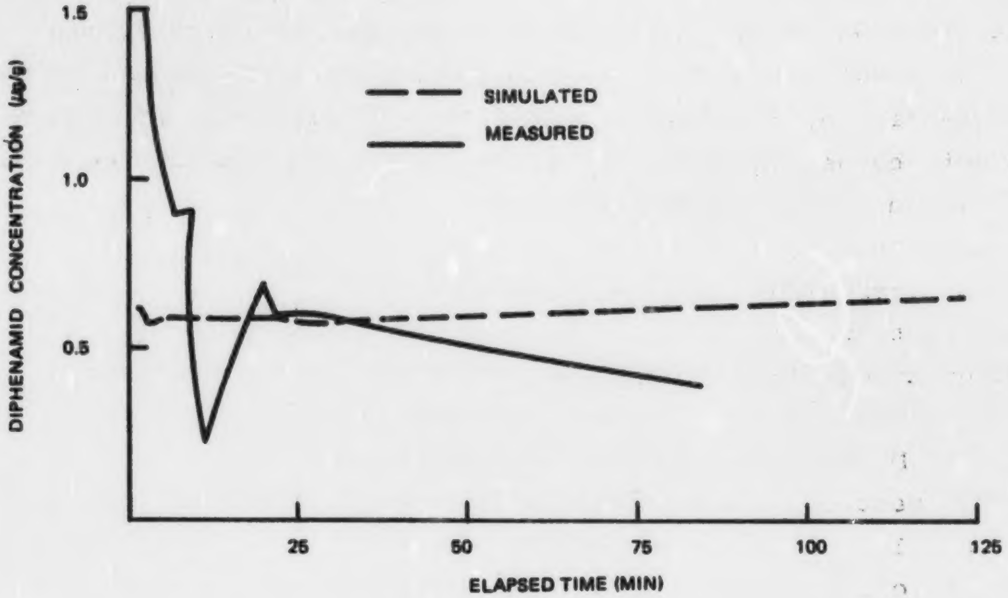


Figure 46. P-01 watershed: diphenamid loss on the sediment (μg/g) for the June 13, 1973, storm

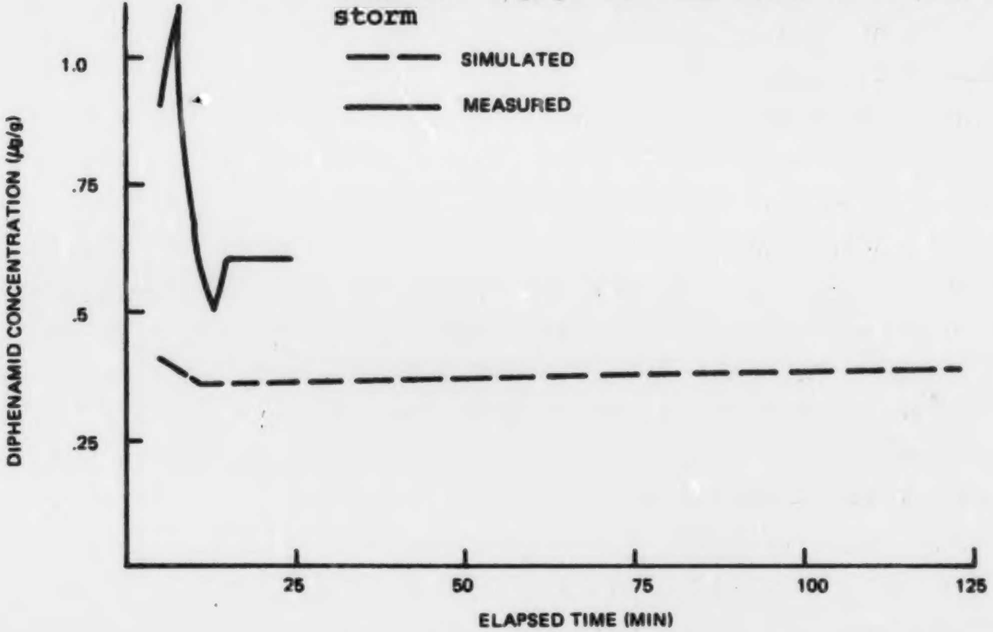


Figure 47. P-01 watershed: diphenamid loss on the sediment (μq/g) for the June 21, 1973, storm

Simulated pesticide concentration on the sediment is constant for several reasons: (1) the exponential factor in the model does not change within a runoff event, (2) the average concentration of adsorbed pesticide in the upper two centimeters does not change significantly during the runoff period, (3) the application of pesticide was assumed to be a constant over the entire watershed, and (4) the present model averages the concentrations from each subplot at the confluence of the watershed. Significant changes in the model and simulation structure will be required to eliminate this effect.

PESTICIDE MOVEMENT IN THE SOIL PROFILE

The pesticide movement model (ADDE) (described in detail in Section VII of this report) simulates the movement of pesticides into the soil and the dispersal of the pesticide in the soil profile. The pesticides modeled in the simulation were diphenamid and atrazine, which were applied, respectively, to watersheds P-01 and P-04. Both of the pesticides are water soluble and were applied as a wettable powder at a rate of 3.36 kg/ha.

The adsorption-desorption model requires four input parameters: AB and N, the exponential coefficients; K, the adsorption coefficient; and D, the diffusion coefficient. The adsorption-desorption model is also sensitive to the thickness of the soil layer, which is a user supplied parameter determined by the requirements of other submodels. The adsorption coefficient, K, was the only parameter assigned different values (see Table 4) for diphenamid and atrazine. The movement of pesticides into the soil profile interacts with several other processes involved in the simulation of pesticide transport on a watershed. The degradation model, DEGRAD, determines the remaining level of pesticide, which is available for movement by the adsorption-desorption model. The infiltration model, WATER, and evapotranspiration model, EVAP, provide the water movement parameters which effect the rates of adsorption-desorption and pesticide dispersion. In order to evaluate the results of ADDE, while minimizing the effects of DEGRAD, pesticide concentrations are discussed as the percentage per soil level of the total pesticide concentration remaining in the soil. The dependence upon infiltration velocities calculated by WATER cannot be eliminated in the analysis of the ADDE submodel.

To compare the simulated results of ADDE to the core sample data, the SCRAM results were adjusted from the 1 cm soil layers, predicted by the model, to the experimental core sample intervals (Figure 48). Model predictions were made to a soil depth of 15 cm, which corresponds to the first five core sample intervals (0-1.0 cm, 1-2.5 cm, 2.5-5.0 cm, 5.0-7.5 cm, and 7.5-15.0 cm). Experimental sample levels between 15-22.5 cm and 22.5-30 cm are not shown because significant movement did not occur below 15 cm. The procedure used to convert pesticide concentration from ppb to percent is shown in Table 5.

Both the measured and simulated data points were plotted as bars and then a smooth curve drawn to reduce the distortion caused by the sampling levels. The bars are not shown on the graphs because they obscure the difference between the simulated and measured profiles.

Diphenamid Movement and Dispersion on P-01

The first storm after diphenamid application occurred on the same day, June 13, 1973. Significant amounts (6%) of diphenamid were found below five centimeters, whereas the model predicts all of the pesticide should be above five centimeters (Figure 49).

TABLE 4. ADDE PARAMETERS USED IN THE SCRAM SIMULATION OF PESTICIDE MOVEMENT ON WATERSHEDS P-01 AND P-04

Watershed	Pesticide	Parameter Description	Parameter	Parameter Value
P-01	Diphenamid	Exponential Coefficient	AB	1.7
P-01	Diphenamid	Exponential Coefficient	N	0.9
P-01	Diphenamid	Adsorption Coefficient	K	1.5
P-01	Diphenamid	Diffusion Coefficient	D	0.1
P-04	Atrazine	Exponential Coefficient	AB	1.7
P-04	Atrazine	Exponential Coefficient	N	0.9
P-04	Atrazine	Adsorption Coefficient	K	1.0
P-04	Atrazine	Diffusion Coefficient	D	0.1

TABLE 5. PROCEDURE FOR CALCULATING THE PERCENT PESTICIDE PER SAMPLE LEVEL

Level	Depth	Concentration	Mass*	Percent
#	cm	ppb	ng	%
1	0-1	26,000	39,000	78
2	1-2.5	1,455	3,274	6
3	2.5-5.0	1,322	4,958	10
4	5.0-7.5	500	1,875	4
5	7.5-15.0	107	1,205	2

* Soil bulk density = 1.5 g/cm^3

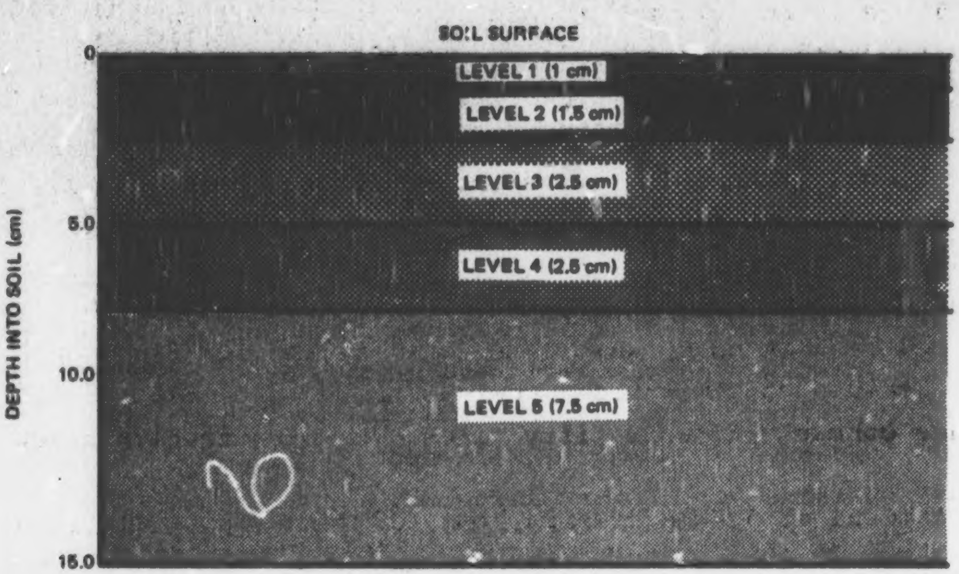

SOIL SURFACE
LEVEL 1 (1 cm)
LEVEL 2 (1.5 cm)
LEVEL 3 (2.5 cm)
LEVEL 4 (2.5 cm)
LEVEL 5 (7.5 cm)
DEPTH INTO SOIL (cm)
0
5.0
10.0
15.0

Figure 48. Diagram of core samples used in analysis of experimental data

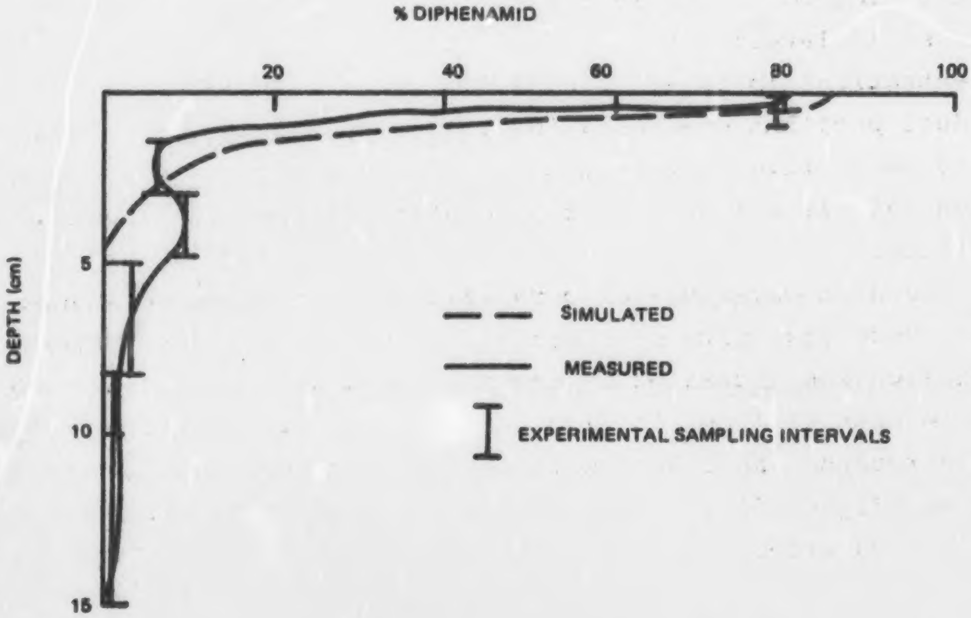


Figure 49. P-01 watershed: simulated and measured distribution in the soil profile on June 13, 1973

There is no obvious explanation for the difference. The storm produced 1.9 cm of rain over a 26 minute period and 1.37 cm was runoff, leaving 0.53 cm to infiltrate into the soil profile. This is not enough water to carry pesticide below 10 centimeters. The residual diphenamid levels on P-01 measured on June 12, 1973, are insignificant in comparison to the levels measured on June 13, 1973. Interestingly, the same type of distribution was measured on P-03 on June 15, 1973, even though no rainfall was recorded on that date (which was also the application date). Hence, sample contamination seems probable, especially since the surface concentration is fifty times the concentration below 5 cm.

A total of 5.0 cm of rain, most of which was infiltrated, fell between June 13, 1973, and the next sample date, which was July 9, 1973. The simulated distribution has started to move into the soil profile, whereas the measured distribution still shows the highest percentage at the soil surface (Figure 50). By this time more than 90 percent of the diphenamid has been degraded in levels one, two, and three (0-5 cm), while the concentrations in levels four and five have returned to the residual preplant concentrations. Hence, the portion of the curves below five centimeters is of little significance, even though this is a significant percentage of the total remaining pesticide.

The next experimental core samples were taken on August 1, 1973. More than five centimeters of rain fell in the interim. Dispersion has increased in the simulated pesticide distribution and the peak is close to five centimeters. The measured distribution retains the characteristic higher concentration at the surface (Figure 51). The same type of distribution was observed on the P-03 watershed.

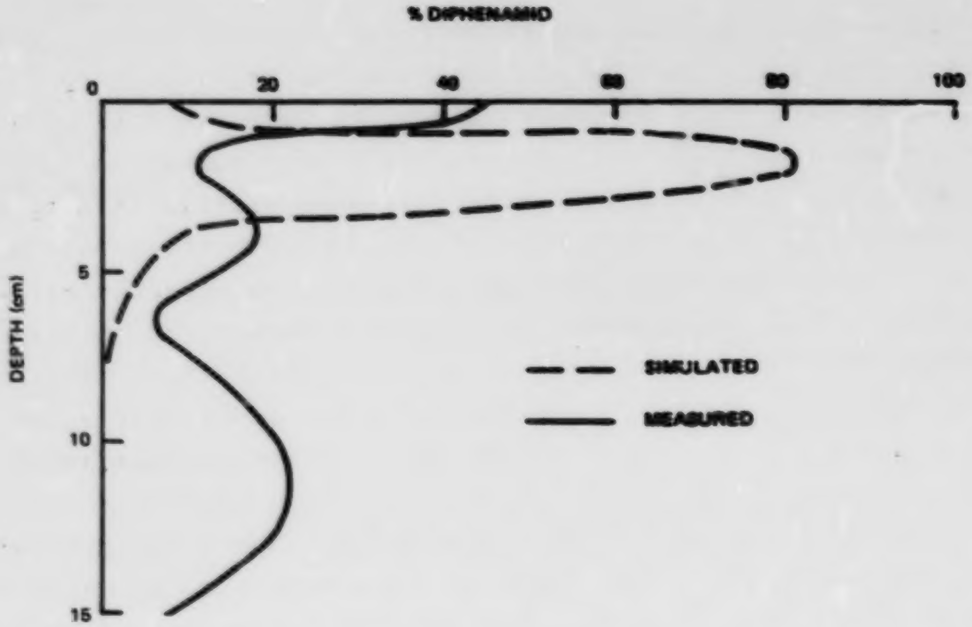


Figure 50. P-01 watershed: simulated and measured distribution in the soil profile on July 8, 1973

One explanation for this, which has been postulated by SERL staff, is that some of the diphenamid may be permanently attached to the soil particles. Although permanent attachment would only occur for a small percentage of the pesticide, as the season progressed the concentration at the surface would not be depleted by infiltration.

The final core samples were taken on September 12, 1973. By this time most of the diphenamid has degraded. There is very little difference between the measured concentrations below one centimeter and the residual concentrations measured before application. The measured concentration in the first centimeter is slightly higher than the preapplication residual, but is of doubtful significance due to the effects of soil erosion and sediment deposition. Simulated concentrations are zero in the top few centimeters due to the effects of degradation and the amount of water that has infiltrated into the soil.

Atrazine Movement and Dispersion on P-04.

Atrazine was surface applied to P-04 on May 11, 1973. A total of 13.98 centimeters of rain fell between the application date and May 30, 1973. Approximately 8.4 centimeters of the rain was infiltrated. The measured atrazine profile is dispersed wider and deeper in the soil profile than in the simulated profile (Figure 52). Since simulated runoff was below measured runoff for the same period, the difference is not due to the WATER model.

Between May 30, 1973, and June 8, 1973, an additional 9 centimeters of rain fell, of which approximately 6 centimeters was infiltrated. The simulated atrazine distribution is reasonably close to the measured profile (Figure 53). There are two differences: (1) the simulated atrazine concentrations are close to zero and below measured concentrations at the surface, and (2) the simulated atrazine concentrations below 8 centimeters are less than measured levels. The difference at the surface is probably partially due to the effects of sediment movement and deposition and sampling difficulties. Atrazine movement in significant amounts below 8 centimeters is not expected for the present model and specified parameters.

On July 10, 1973, the final set of core samples were taken on P-04. Ten centimeters of rain fell in the interim (6.4 centimeters on July 8, 1973) and approximately 7 centimeters was infiltrated. The simulated and measured distributions are markedly different (Figure 54). Very little atrazine remains on the watershed at this time (< 3 percent), hence the difference is not particularly significant. Nevertheless, the characteristic presence of measureable levels of atrazine at the surface and below ten centimeters is evident.

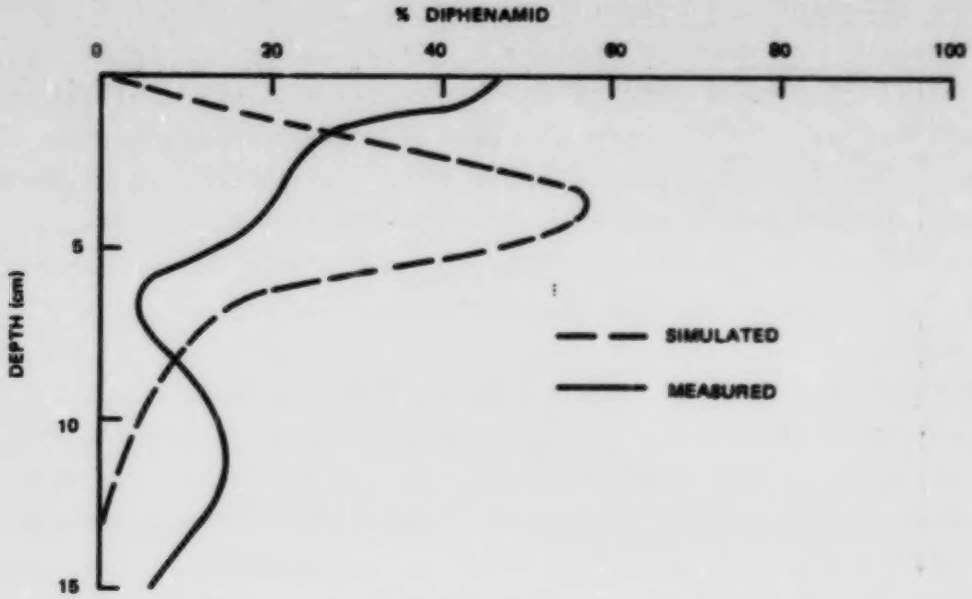


Figure 51. P-01 watershed: simulated and measured distribution in the soil profile on August 1, 1973

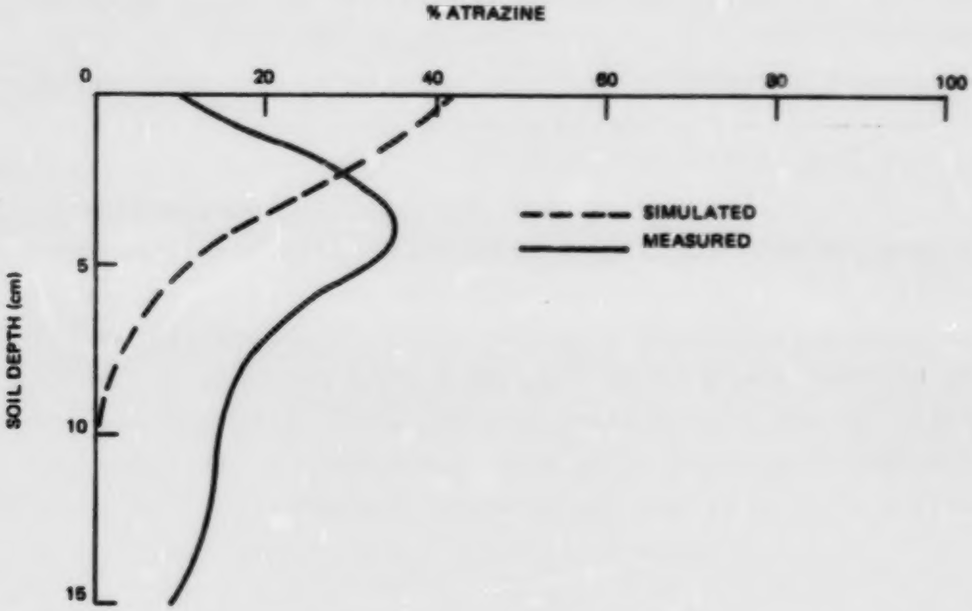


Figure 52. P-04 watershed: simulated and measured distribution in the soil profile on May 23, 1973

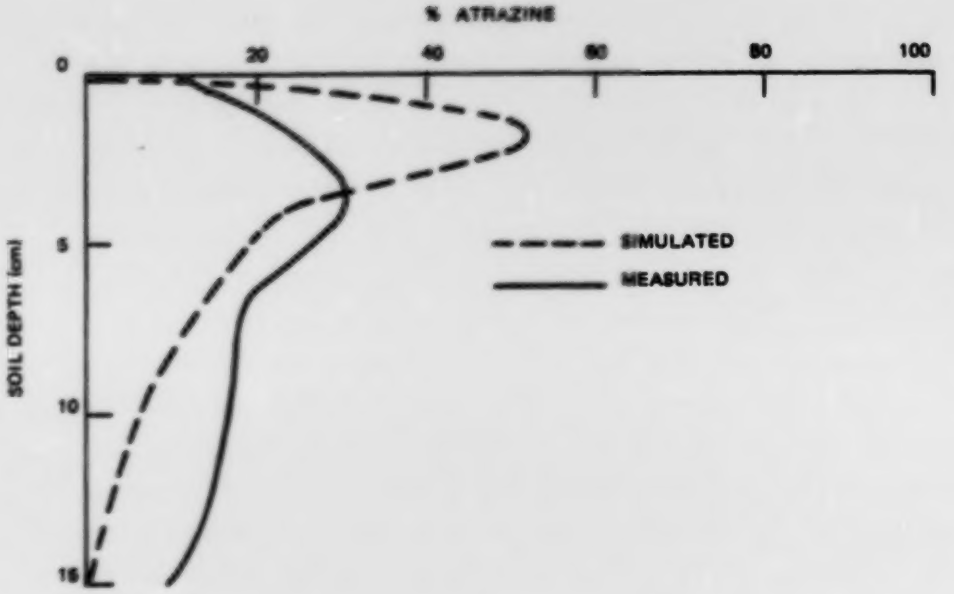


Figure 53. P-04 watershed: atrazine soil profile distribution on June 8, 1973

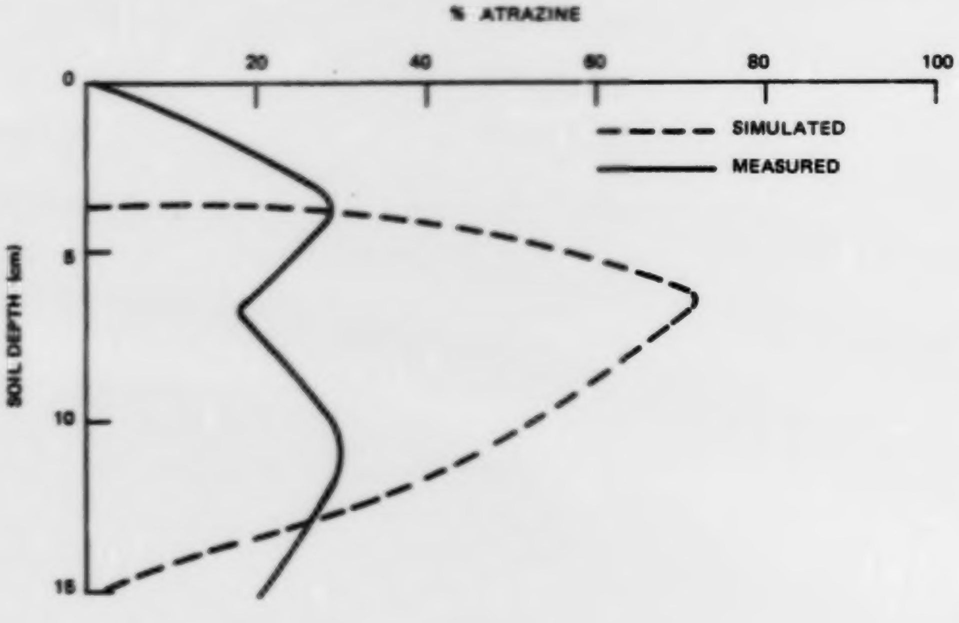


Figure 54. P-04 watershed: atrazine soil profile distribution on July 10, 1973

As noted above, the interdependences between the simulation submodels makes it difficult to assess the adequacy of the adsorption-desorption submodel. However, a few observations are in order. The presence of pesticide is suspect below ten centimeters immediately after application and before significant rainfall has occurred. Sample contamination seems likely. The persistence of pesticide in the upper few centimeters of soil throughout the season is unexpected. This could be explained if some of the pesticide is adsorbed permanently. The permanently adsorbed pesticide would not be moved into the soil profile and could be less susceptible to degradation processes. Finally, significant distortion of the pesticide profile may result from the sampling intervals used in the measurement program. The effect is partially compensated by distorting the simulated data in the same fashion However, considering the rate of degradation and the experimental problems involved, sampling intervals of 0-2 cm, 2-4 cm, 4-6 cm, 6-8 cm, 8-10 cm, and 10-20 cm are preferable.

DEGRADATION

The simulation of the diphenamid degradation on the P-01 watershed utilizes two simplifying assumptions. The first assumption is uniform application of the herbicide over the watershed. The figure used in the simulation as the application rate was 33.66 $\mu g/cm^2$, based on a uniform application of 3.36 kg/ha.

The second assumption, which may have significantly influenced the simulation results, involves the soil temperature. A uniform soil temperature in the range of 25-28°C was assumed throughout the soil profile. Temperature profile data from the attenuation plots could not be used because of data gaps and inconsistencies. In addition, the number of input cards to the simulation would be unmanageable if soil temperature profiles were included.

As a result of assuming that soil temperature is uniform, the degradation rate in the upper levels is below actual. During periods when the soil is dry the degradation model is not particularly sensitive to soil temperature. During periods when the soil is moist the temperature profile is more nearly uniform. As the crop canopy develops the soil temperature gradient is reduced. Finally, the adsorption-desorption model rapidly removes pesticide from the soil surface and hence the uniform soil temperature assumption will not have a significant effect on the simulation results.

The experimental core samples were collected from each of the ten subplots on P-01. There is a large variation among samples from the same level but different subplots. Comparison between simulated and measured levels on a subplot basis is also difficult due to the effects of sediment transport and deposition. Because of this the simulated and experimental results for each subplot and all levels were averaged to produce a watershed degradation curve.

Diphenamid degradation for P-01, simulated and measured, is plotted in Figure 55. Measured degradation is much more rapid than simulated degradation. Within 30 days 95 percent of the diphenamid has been degraded and within 60 days nearly 99 percent has been degraded. Simulated degradation proceeds at a slower rate but does approach 100 percent after 90 days, which is consistent with the model.

The same model assumptions and parameters were used to simulate atrazine degradation on P-04 (Figure 56). Measured degradation is very rapid during the first 30 days (~ 95%) and only trace amounts remain after 60 days. The simulated degradation

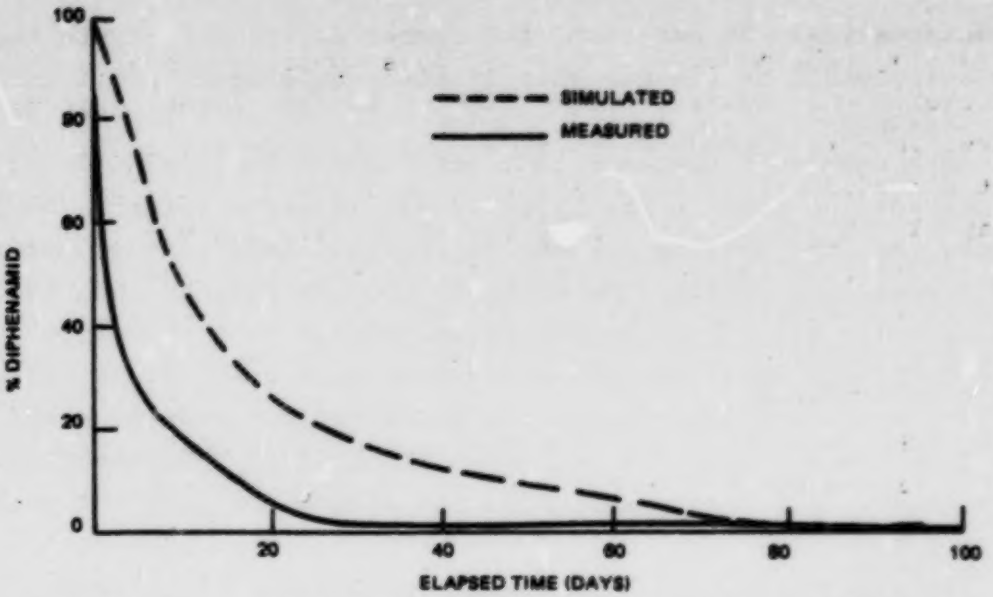


Figure 55. P-01 watershed: degradation of diphenamid in the soil profile after application on June 13, 1973

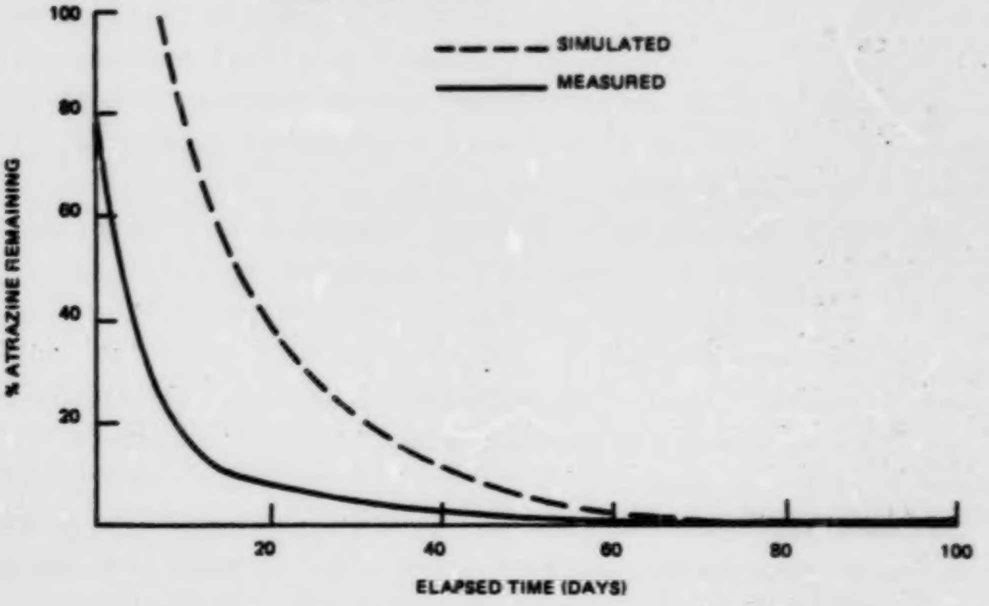


Figure 56. P-04 watershed: degradation of atrazine in the soil profile after application on May 11, 1973

curve lags the measured curve but does approach the axis asymptotically as required by the model. The simulated degradation curve is offset from the vertical axis because the pesticide is not introduced into the simulation until the first rain occurs (May 19, 1973), whereas the application date was May 11, 1973.

Simulated degradation depends on the soil moisture profile, the soil temperature profile, and the pesticide distribution in the soil profile. The infiltration model and the evapotranspiration model determine the soil moisture profile. At the present time SCRAM does not contain a soil temperature model. The adsorption-desorption model results suggest that pesticide is moved into the soil profile too rapidly. The combined effect of these three models on the degradation results is difficult to determine because in this model parameters were not adjusted from specified values to improve the results. Also, based upon the sensitivity analyses (Section VII), even if the degradation parameters are set for maximum degradation the simulated rate of degradation would be below the measured rate. Because of this the degradation model may require further development to improve the simulated results.

VOLATILIZATION

Trifluralin (α, α, α-trifluoro - 2, 6-dinitro-N, N-dipropyl-p-toluidine) was selected to test the volatilization submodel included in SCRAM. Trifluralin was applied to both the P-01 and P-03 watersheds. Data was available from the date of application on the total amounts of trifluralin still on the watershed and the amount of trifluralin distributed in the soil profile.

The application rate on both watersheds was specified as 1.12 kg/ha (incorporated). However, immediately after application the average of the core samples indicated that a large amount of trifluralin had already been lost (38 to 56%) due to volatilization or experimental error.

Uncertainty in the application amount and/or rapid volatilization also creates uncertainty as to what the initial pesticide distribution in the soil profile should be. Figure 57 is a graph of the initial pesticide profile at the time of the first observation during 1973 on P-01 and P-03. Also shown in Figure 57 is a starting profile distribution that was frequently used during the simulation.

The simulation was started with a trifluralin profile which was higher than measured in the upper layers and below measured concentration in the lower layers. This is intended to allow for losses and redistribution before the first samples were taken. The simulated application amount was taken as 5700 ng/cm^2 unless noted otherwise.

Initially, the diffusion coefficient for trifluralin at each depth increment was calculated from the equation developed by Bode[20] for Mexico Silt Loam (2.5% organic matter, 75% silt, 22% clay and a pH of 5.6). This was not successful because at the present time SCRAM does not contain a model to predict the soil temperature profile and at a bulk density of 1.6 g/cc the Bode equation generates diffusion coefficients which are less than 3×10^{-7} cm^2/sec if the soil temperature is below 40°C.

Diffusion coefficients for trifluralin in Lanton Silty Clay Loam between 0.2 and 0.5 x 10^{-7} cm^2/sec have been reported.[21] Diffusion coefficients less than 10^{-7} cm^2/sec do not cause significant losses of trifluralin with the present model.

One explanation for the unusually large diffusion coefficients required in the model would be the effect of significant degradation. However, there is no positive evidence of photodecomposition on soils and microbial degradation is minimal.[22]

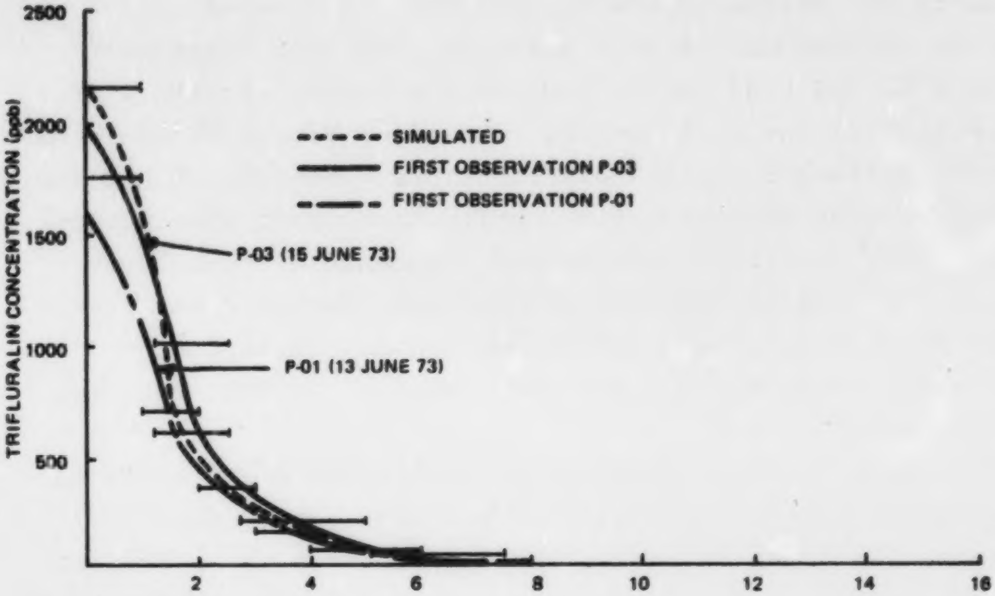


Figure 57. Distribution of trifluralin in the soil profile

Because of this it was necessary to treat the diffusion coefficient as a constant independent of soil temperature and soil moisture content. As a result the diffusion coefficient becomes a simulation parameter.

There is very little difference between the P-01 and P-03 trifluralin losses as a function of time. Figures 58 and 59 show the percent of trifluralin remaining since the application date for the P-01 watershed. The solid curves represent the smoothed data for two different application rates. Curves labeled "I" represent an application rate derived by adding 10% to the amount found at the time of the first sampling. Curves labeled "II" represent the amount remaining if 11,220 ng/cm^2 was applied.

Since the diffusion coefficient must be treated as a parameter independent of soil moisture, the only difference between P-01 and P-03 is the application amount and the initial distribution in the soil profile. Based on Figure 57 there may have been different initial distributions. However, the different rainfall records observed after application could also account for the different profile distributions. Because of these uncertainties the loss of trifluralin has been simulated for several initial distributions and several values of the diffusion coefficient. The results were then compared to both P-01 and P-03 experimental data.

The first trifluralin distribution tested was similar to that observed on P-03 on a percent per centimeter basis. Represented as a vector basis, the distribution is as follows: 45.8, 27.5, 14.2, 6.4, 3.3, 1.8, 0.8, 0.2. The diffusion coefficient was set at 8×10^{-7} cm^2/sec (6.9×10^{-2} cm^2/day). As shown in Figures 58 and 59 (curves labeled "A"), the simulated trifluralin loss follows the observed loss closely for the first 25 to 30 days and then falls behind when compared to an application rate ("I") near that observed on the day of application. If the assumed application rate is near the specified rate, the diffusion coefficient must be increased by a factor of 100 to produce results which compare to those measured. See Figure 58 and 59 curves "II" and "C".

Regardless of how the initial profile is specified or how large the diffusion coefficient is, the present model does not adequately predict the loss of trifluralin. Observed losses drop off rapidly during the first 20 days or so and then seem to drop in a linear fashion during the remaining 70-80 days. None of the available models will predict this behavior.

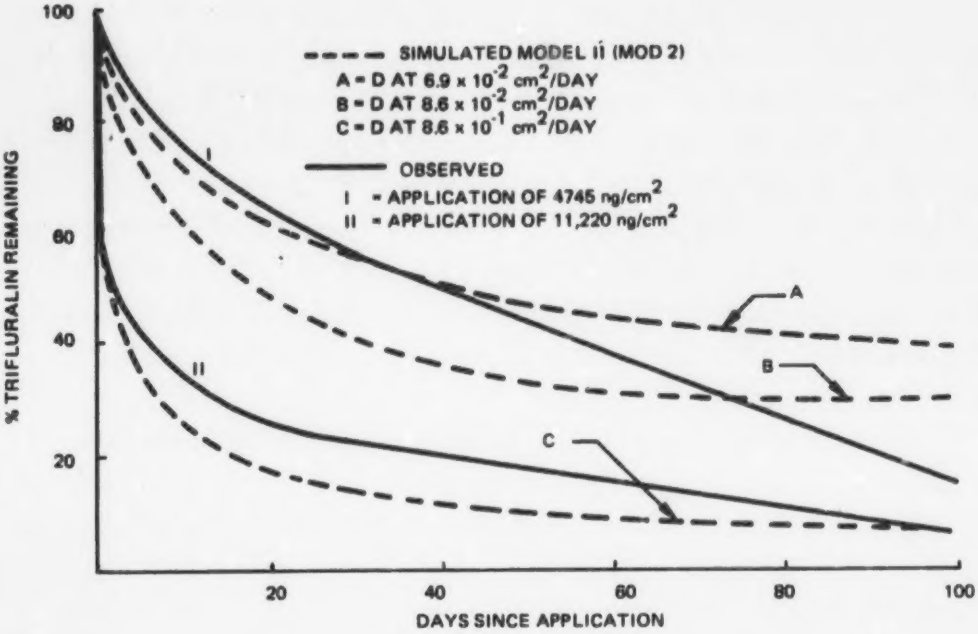


Figure 58. P-01 watershed: trifluralin remaining after application date

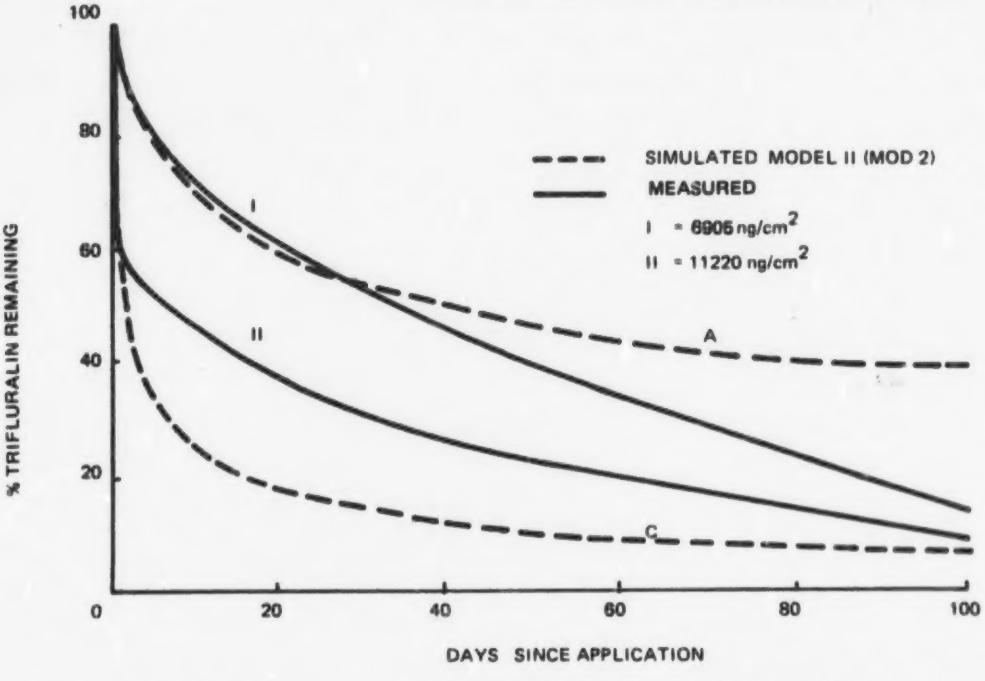


Figure 59. P-03 watershed: trifluralin remaining after application data

The volatilization model designated as Model II (Mod 2) also predicts diffusion of pesticide in the soil profile according to the concentration gradient. Experimental data shown in Figures 60 and 61 illustrate the tendency for the pesticide to approach a nearly uniform distribution in the soil profile. Simulation results for two different values of the diffusion coefficient are shown in Figures 62 and 63. Although the simulation results are calculated on a per centimeter basis, they have been graphed to correspond to the experimental depth increments.

The volatilization model predicts pesticide movement in the soil profile in close agreement with the experimental results. Simulated volatilization loss does not correlate well with the periodic measured loss, and unusually large values for the diffusion coefficient are required to predict total losses which approach measured losses.

SIX MONTH SUMMARY

In the previous sections the simulation results were discussed for each major runoff event. A large number of storms occurred between the major events which were not discussed. Runoff, sediment, and pesticide loss for the entire period simulated are presented below as an aid in evaluating the simulation results.

Table 6 displays the simulated and measured results for P-01 (2.70 ha) between June 13, 1973, and December 31, 1973. A total of 49.6 cm of rain was recorded, producing 2,179,497 liters of runoff (16%) and 29,999 kilograms of sediment. Measured diphenamid loss was 652 grams or 7 percent of the total

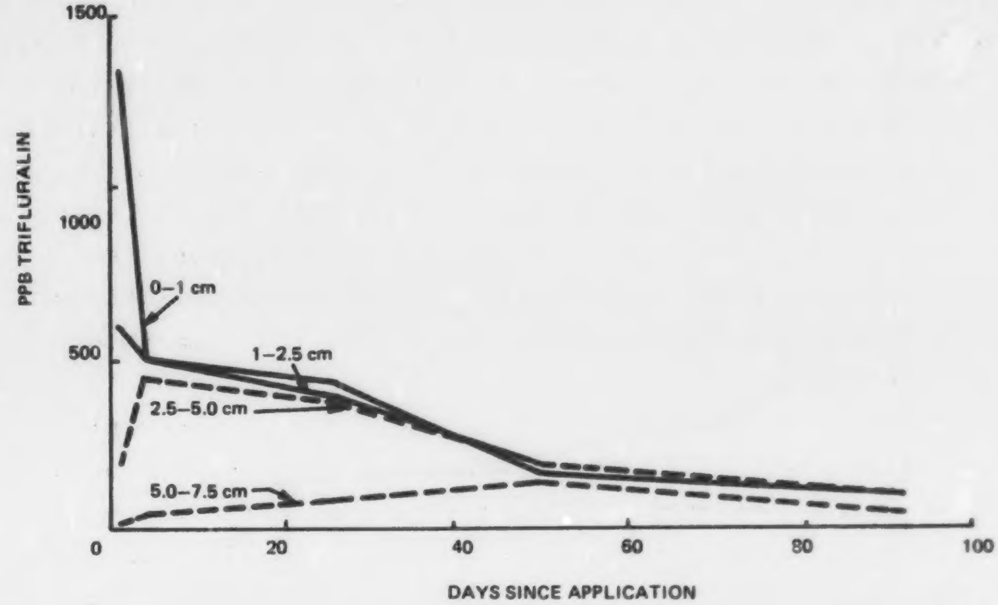


Figure 60. P-01 watershed: average trifluralin concentration as a function of soil depth - 1973

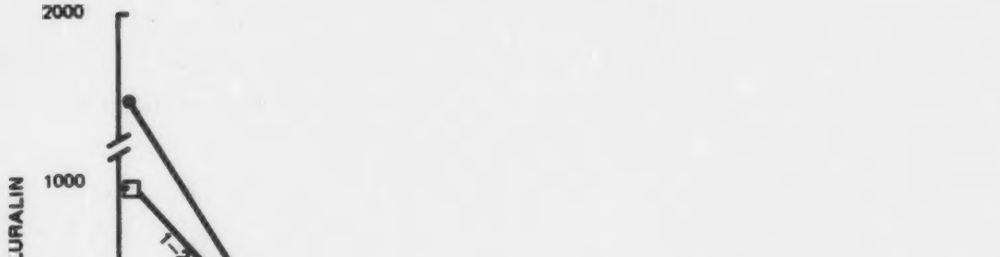


Figure 61. P-03 watershed: average trifluralin concentration as a function of soil depth - 1973

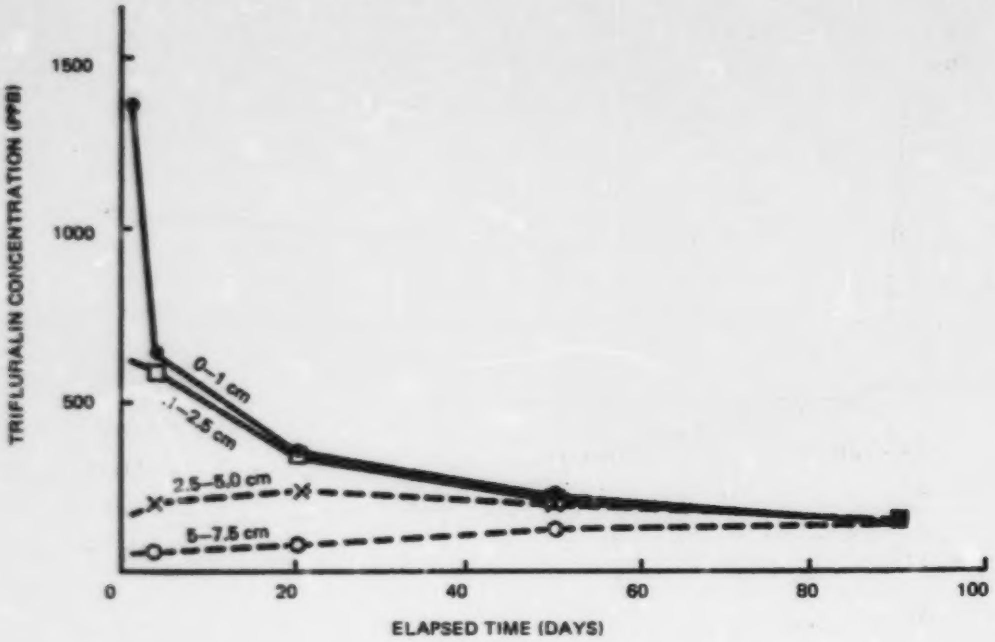


Figure 62. P-01 watershed: simulated volatilization and diffusion of trifluralin from June to September, 1973 ($D = 10. \times 10^{-6}\ cm^2/sec$)

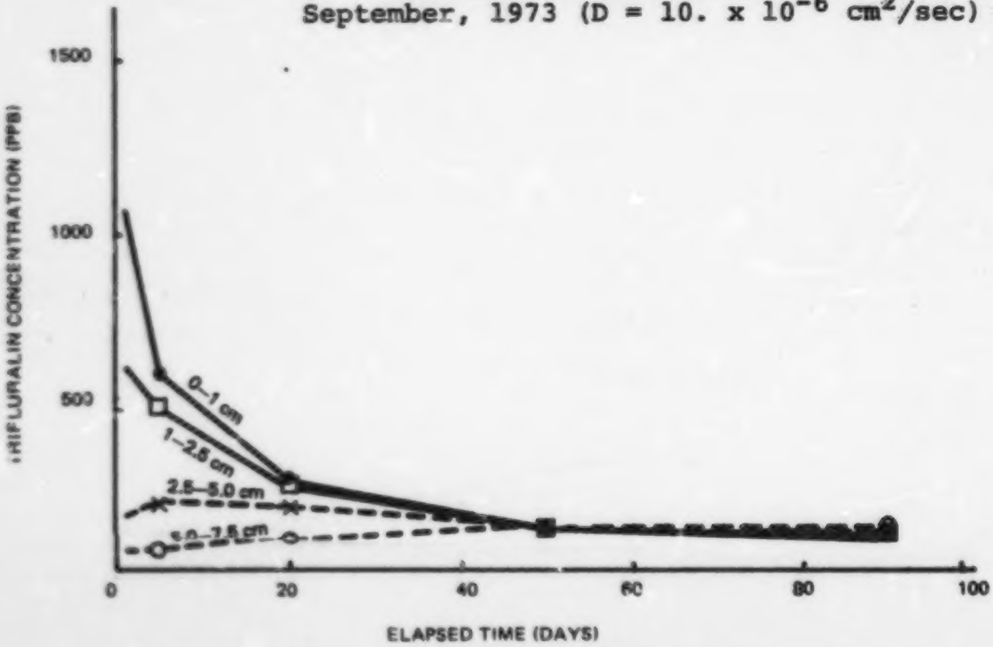


Figure 63. P-01 watershed: simulation volatilization and movement of trifluralin from June to September, 1973 ($D = 2 \times 10^{-6}\ cm^2/sec$)

Table 6. P-01 WATERSHED: MEASURED VS. SIMULATED RUNOFF, SEDIMENT AND DIPHENAMID LOSS - JUNE TO DECEMBER, 1973

STORM DATE AND RAINFALL (cm)	RUNOFF* (l)	SEDIMENT* (kg)	DIPHENAMID LOSS* (g)		
			SEDIMENT	RUNOFF	TOTAL
13 JUNE 73 (1.9)	369,445 336,287	16,388 14,456	10.5 8.8	608. 556.	618.5 564.8
20 JUNE 73 (0.10)	– –	– –	– –	– –	– –
21 JUNE 73 (1.9)	112,397 183,487	2,367 7,257	1.59 2.76	27.6 133.	29.2 178.8
25 JUNE 73 (0.51)	– –	– –	– –	– –	– –
28 JUNE 73 (0.41)	– –	– –	– –	– –	– –
28 JUNE 73 (0.38)	15,763 –	259 –	0.05 –	1.02 –	1.07 –
8 JULY 73 (1.7)	132,821 32,938	1,361 284	0.22 0.01	1.77 4.16	1.99 4.17
16 JULY 73 (0.89)	– –	– –	– –	– –	– –
17 JULY 73 (0.76)	25,824 11,187	133 99	0.05 0.002	0.26 0.05	0.31 0.052
25 JULY 73 (0.38)	– –	– –	– –	– –	– –
30 JULY 73 (2.79)	364,674 457,400	3,925 21,468	0.47 0.19	0.71 1.50	1.18 1.69
1 AUGUST 73 (0.64)	– –	– –	– –	– –	– –
17 AUGUST 73 (1.14)	2,099 35,223	13 1,922	0.008 0.0004	0.02 0.003	0.03 .0034
18 AUGUST 73 (0.89)	34,167 45,789	213 4,114	0.017 –	0.034 –	0.05 –
31 AUGUST 73 (0.51)	– –	– –	– –	– –	– –
3 SEPTEMBER 73 (0.69)	– –	– –	– –	– –	– –
9 SEPTEMBER 73 (4.06)	400,461 641,508	2,078 15,060	0.129 –	– –	0.13 –
13 SEPTEMBER 73 (3.18)	224,742 286,226	958 3,493	– –	– –	– –
14 SEPTEMBER 73 (0.69)	– 10,625	– 45	– –	– –	– –

*MEASURED
SIMULATED

Table 6. - Continued.

STORM DATE AND RAINFALL (cm)	RUNOFF* (l)	SEDIMENT* (kg)	DIPHENAMID LOSS* (g)		
			SEDIMENT	RUNOFF	TOTAL
17 SEPTEMBER 73 (0.38)	– –	– –	– –	– –	– –
18 SEPTEMBER 73 (0.46)	– –	– –	– –	– –	– –
27 SEPTEMBER 73 (0.76)	–	–	–	–	–
28 SEPTEMBER 73 (0.38)	– –	– –	– –	– –	– –
31 SEPTEMBER 73 (1.40)	– 7,981	– 33	– –	– –	– –
30 OCTOBER 73 (0.86)	– –	– –	– –	– –	– –
21 NOVEMBER 73 (2.08)	– 61,956	– 318	– –	– –	– –
25 NOVEMBER 73 (0.58)	– –	– –	– –	– –	– –
26 NOVEMBER 73 (0.38)	– –	– –	– –	– –	– –
28 NOVEMBER 73 (1.40)	– –	– –	– –	– –	– –
4 DECEMBER 73 (0.20)	– –	– –	– –	– –	– –
5 DECEMBER 73 (3.99)	21,360 458,169	12 2,939	– –	– –	– –
15 DECEMBER 73 (1.65)	– –	– –	– –	– –	– –
16 DECEMBER 73 (0.25)	– –	– –	– –	– –	– –
20 DECEMBER 73 (1.93)	7,362 84,076	7 367	– –	– –	– –
25 DECEMBER 73 (1.19)	– –	– –	– –	– –	– –
26 DECEMBER 73 (0.64)	– –	– –	– –	– –	– –
30 DECEMBER 73 (2.51)	– 63,404	– 1,743	– –	– –	– –
31 DECEMBER 73 (5.26)	478,382 667,600	2,285 4,001	– –	– –	– –
TOTALS	2,179,497 3,372,886	29,999 77,599	13. 11.	639. 695.	652. 706.

*MEASURED
SIMULATED

application. Ninety-eight percent of the measured diphenamid loss was in the runoff (639 grams), with only 2 percent (13 grams) on the sediment. Ninety-five percent of the loss occurred on the application date as a result of a cloudburst of 1.9 cm of rain which produced 72 percent runoff.

SCRAM used the 49.62 cm of rain as input and predicted a total of 3,372,866 liters of runoff (25%) and 77,599 kilograms of sediment using clay soil parameters. Simulated diphenamid loss was 706 grams, 695 grams in the runoff, and 11 grams on the sediment. Changing the soil parameters to SERL loam reduces simulated runoff to 1,418,231 liters and sediment loss to 15,769 kilograms.

Summary results for the P-04 (1.38 ha) watershed between May 19, 1973, and December 31, 1973, are presented in Table 7. A total of 83.82 cm of rain was recorded on P-04, producing measured runoff of 2,356,473 liters (20%) and measured sediment loss of 5,525 kilograms. Total atrazine loss was 39 grams (<1%), 37 grams in the runoff and 2 grams on the sediment. The difference between P-01 and P-04, with respect to pesticide loss, is probably due to the occurrence of heavy runoff on the application date on P-01.

Simulated runoff on P-04 using SERL loam soil parameters was 1,876,846 liters (16%). Simulated sediment loss was only 348 kilograms (6% of measured) using P-01 parameters. Simulated atrazine loss was 164 grams (4%) all of which was in the runoff because of the low sediment predictions.

The low simulated sediment losses on P-04 were unexpected. Based upon the differences in slope and watershed size the same rainfall on P-04 should produce approximately 25% as much sediment as on P-01. Although no exact comparisons are possible, the difference between simulated values is much larger than 25%.

Table 7. P-04 WATERSHED: MEASURED VS. SIMULATED RUNOFF, SEDIMENT, AND ATRAZINE LOSS - MAY TO DECEMBER, 1973

STORM DATE AND RAINFALL (cm)	RUNOFF* (l)	SEDIMENT* (kg)	ATRAZINE LOSS * (g)		
			SEDIMENT	RUNOFF	TOTAL
19 MAY 73 (2.64)	– 13,361	– 6	– TRACE	– 17.3	– 17.3
23 MAY 73 (1.22)	2,609 6,365	14 3	0.008 TRACE	0.411 4.53	0.42 4.53
24 MAY 73 (0.97)	– –	– –	– –	– –	– –
26 MAY 73 (4.83)	356,894 263,700	1,609 107	0.88 TRACE	17.4 87.2	18.28 87.2
28 MAY 73 (4.32)	337,243 187,860	1,613 48	0.79 TRACE	14.4 44.0	15.9 44.0
1 JUNE 73 (0.64)	– –	– –	– –	– –	– –
5 JUNE 73 (1.02)	– –	– –	– –	– –	– –
6 JUNE 73 (3.94)	280,583 241,810	796 72	0.27 TRACE	3.07 9.3	3.34 9.3
7 JUNE 73 (2.29)	– –	– –	– –	– –	– –
7 JUNE 73 (1.12)	80,515 55,040	276 12	0.07 TRACE	0.81 1.21	0.88 1.21
13 JUNE 73 (0.89)	16,772 1,970	43 1	0.01 TRACE	0.20 0.08	0.21 0.08
20 JUNE 73 (0.97)	– –	– –	– –	– –	– –
21 JUNE 73 (0.48)	– –	– –	– –	– –	– –
26 JUNE 73 (0.61)	– –	– –	– –	– –	– –
28 JUNE 73 (0.58)	– 200	– –	– –	– –	– –
4 JULY 73 (0.30)	– –	– –	– –	– –	– –
8 JULY 73 (6.4)	411,186 464,060	756 78	0.04 TRACE	0.41 0.007	0.45 0.01
14 JULY 73 (1.9)	61,563 49,800	59 7	0.004 –	0.06 –	0.06 –
16 JULY 73 (0.33)	– –	– –	– –	– –	– –
17 JULY 73 (0.94)	9,327 –	12 –	– –	– –	– –

* MEASURED
SIMULATED

Table 7. - Continued.

STORM DATE AND RAINFALL (cm)	RUNOFF* (l)	SEDIMENT* (kg)	ATRAZINE LOSS* (g)		
			SEDIMENT	RUNOFF	TOTAL
23 JULY 73 (1.27)	– –	– –	– –	– –	– –
25 JULY 73 (0.89)	– –	– –	– –	– –	– –
28 JULY 73 (0.25)	– –	– –	– –	– –	– –
31 JULY 73 (0.25)	– –	– –	– –	– –	– –
1 AUGUST 73 (0.32)	– –	– –	– –	– –	– –
6 AUGUST 73 (0.13)	– –	– –	– –	– –	– –
14 AUGUST 73 (0.64)	– –	– –	– –	– –	– –
17 AUGUST 73 (0.25)	– –	– –	– –	– –	– –
18 AUGUST 73 (0.38)	– –	– –	– –	– –	– –
31 AUGUST 73 (0.25)	– –	– –	– –	– –	– –
3 SEPTEMBER 73 (0.38)	– –	– –	– –	– –	– –
9 SEPTEMBER 73 (4.45)	163,449 226,900	89 6	– –	– –	– –
10 SEPTEMBER 73 (0.76)	– –	– –	– –	– –	– –
13 SEPTEMBER 73 (3.43)	132,777 130,700	83 4	– –	– –	– –
14 SEPTEMBER 73 (0.81)	– –	– –	– –	– –	– –
17 SEPTEMBER 73 (1.32)	– –	– –	– –	– –	– –
27 SEPTEMBER 73 (0.51)	– –	– –	– –	– –	– –
28 SEPTEMBER 72 (0.84)	– –	– –	– –	– –	– –
31 SEPTEMBER 73 (1.37)	– –	– –	– –	– –	– –
31 OCTOBER 73 (0.51)	– –	– –	– –	– –	– –

*MEASURED
SIMULATED

Table 7. -- Continued.

STORM DATE AND RAINFALL (cm)	RUNOFF* (l)	SEDIMENT* (kg)	ATRAZINE LOSS* (g)		
			SEDIMENT	RUNOFF	TOTAL
21 NOVEMBER 73 (2.08)	– –	– –	– –	– –	– –
25 NOVEMBER 73 (0.84)	– –	– –	– –	– –	– –
26 NOVEMBER 73 (0.13)	– –	– –	– –	– –	– –
28 NOVEMBER 73 (1.27)	– –	– –	– –	– –	– –
4 DECEMBER 73 (0.13)	– –	– –	– –	– –	– –
5 DECEMBER 73 (3.86)	11,010 52,000	6 1	– –	– –	– –
15 DECEMBER 73 (2.01)	– –	– –	– –	– –	– –
20 DECEMBER 73 (2.62)	49,062 33,100	25 1	– –	– –	– –
25 DECEMBER 73 (2.11)	8,060 –	4.7 –	– –	– –	– –
29 DECEMBER 73 (6.33)	– –	– –	– –	– –	– –
30 DECEMBER 73 (1.88)	13,188 –	4 –	– –	– –	– –
31 DECEMBER 73 (5.38)	422,238 150,000	135 2	– –	– –	– –
TOTALS	2,356,474 1,876,846	5,524.7 348.	2,071 TRACE	36.761 163.63	38.83 163.63

*MEASURED
SIMULATED

Elimination of the limiting term (L) in the model did not change the simulated sediment loss on P-04. Further work will be required to isolate the reasons why the sediment model, as implemented in SCRAM, predicts unusually low values on P-04.

Although the simulated results are not in complete agreement with the measured values of runoff, sediment loss, and pesticide movement, the potential utility of simulation in understanding and developing pesticide control methodologies is evident. If the processes which effect the movement of pesticides are understood, they can be expressed mathematically and used to develop a model which in turn can be used to simulate the behavior of the system under a variety of conditions. If the model parameters are related to physical quantities which can be measured in the laboratory, rather than empirical fitting parameters, then new pesticide formulations can be "field tested" via simulation against a variety of simulated experimental conditions in a matter of hours.

The next section of this report contains sensitivity analyses of each of the submodels. This section is presented last because it is highly technical and of primary utility to the SCRAM user rather than the average reader.

SECTION VII

MATHEMATICAL MODELS AND SENSITIVITY ANALYSIS

SCRAM includes a number of mathematical submodels to simulate the complex natural phenomenon associated with the transport, movement, and attenuation of pesticides in the environment. Each submodel is modular; only the necessary inputs and outputs are passed between submodels. At the present time there are six submodels:

1. WATER: An infiltration/percolation model that predicts the amount of runoff on the watershed during each event, and the movement of water into the soil profile during and after an event.

2. SED: A sediment model that predicts the soil erosion process.

3. ADDE: An adsorption/desorption model that predicts the simultaneous concentration of pesticide adsorbed and in solution within the soil matrix.

4. DEGRAD: A degradation model that predicts the amount of pesticide loss due to chemical and microbial processes.

5. VOLT: A model that predicts pesticide loss due to the pesticide's volatile properties.

6. **EVAP:** An evapotranspiration model that predicts water loss due to net solar flux, vapor pressure gradient, and plant metabolisms.

This section includes a discussion of the mathematical equations which are the basis for each of the computer submodels. A sensitivity analysis, performed on each submodel prior to incorporation into SCRAM, is included within the discussion of the model. The SCRAM user should read these sections carefully before attempting to set up the simulation parameters.

WATER SUBMODEL AND SENSITIVITY ANALYSES

The general equations for describing flow in a nondeformable media may be derived by substituting the components of $\overline{V}$ (seepage velocity) from Darcy's law into the equation of continuity.[23,24] The net result for water as an incompressible fluid is:

$$\frac{\partial\theta}{\partial t} = \vec{\nabla} \cdot \left[K(\theta)\,\vec{\nabla}\phi\right] \tag{3}$$

where ϕ = total potential defined in terms of energy per unit weight of water. Using this definition, potential has the dimension of length and is referred to as "head"

$\nabla\phi$ = the gradient of total potential

$K(\theta)$ = hydraulic conductivity

$\vec{\nabla}$ = "del" or "nabla" is the vector differential operator.

For purposes of simplifying the model we have only considered flow in the vertical direction (Z positive upwards). Equation (3) then reduces to

$$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial Z}\left[K(\theta)\,\frac{\partial\phi}{\partial Z}\right] \quad . \tag{4}$$

The system is further simplified by neglecting adsorption potential, chemical potential, osmotic - pressure potential, and thermal potential. Total potential is then the sum of capillary (hydrostatic-pressure only) and gravitational potential so that

$$\phi = \varphi_p + \varphi_g \tag{5}$$

On an energy-per-unit-weight basis:

φ_g = Z = height of the water above the reference datum

Substituting into (4) and letting $\varphi_p = h$ gives

$$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial Z}\left[K(\theta)\,\frac{\partial(h-Z)}{\partial Z}\right] \tag{6}$$

Differentiating

$$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial Z}\left[K(\theta)\,\frac{\partial h}{\partial Z}\right] - \frac{\partial K(\theta)}{\partial Z} \tag{7}$$

These equations assume a unique relationship between the pressure or tension head h and moisture content θ. If this assumption is valid it is possible to apply the chain rule of differentiation to yield:

$$\frac{\partial\theta}{\partial t} = \left(\frac{\partial\theta}{\partial h}\right)\left(\frac{\partial h}{\partial t}\right) \qquad (8)$$

where $\left(\frac{\partial\theta}{\partial h}\right) = C$ = Specific Moisture Capacity.

Substituting into Equation (7) gives

$$C\frac{\partial h}{\partial t} = \frac{\partial}{\partial Z}\left(K(\theta)\frac{\partial h}{\partial Z}\right) - \frac{\partial K(\theta)}{\partial Z} \qquad (9)$$

Using an adaptation of the Crank-Nicolson[25] implicit method for solving differential equations, the numerical form of Equation (9) is:

$$\frac{h_i^j - h_i^{j-1}}{\Delta t} = \frac{\left(h_{i-1}^{j-1} + h_{i-1}^{j} + 2\ \Delta Z - h_i^{j-1} - h_i^j\right)K_{i-1/2}^{j-1/2}}{2(\Delta Z)^2\ C_i^{j-1/2}}$$

$$- \frac{\left(h_i^{j-1} + h_i^{j} + 2\ \Delta Z - h_{i+1}^{j-1} - h_{i+1}^j\right)K_{i+1/2}^{j-1/2}}{2(\Delta Z)^2\ C_i^{j-1/2}} \qquad (10)$$

where the subscripts "i" refer to distance and the superscripts "j" refer to time.

The procedure used to solve Equation (10) is similar to the technique of Hanks and Bowers[26] and is outlined briefly below.

Compile tables which list moisture content θ versus hydraulic head, h, and diffusivity, D. Then proceed as follows:

(a) Estimate $(\Delta t)^{j+1/2} = \frac{.035\ \Delta Z}{I^{j-1/2}}$

where $I^{j-1/2}$ = infiltration rate during the previous time step.

(b) $$K_{i-1/2}^{j-1/2} = D_{i-1/2}^{j-1} \frac{\left(\theta_{i-1}^{j-1} - \theta_{i}^{j-1}\right)}{\left(h_{i-1}^{j-1} - h_{i}^{j-1}\right)}$$

(c) $$D_{i-1/2}^{j-1} = \frac{\sum_{\theta=\theta_L}^{\theta_{i-1}^{j-1}} D\Delta\theta - \sum_{\theta=\theta_L}^{\theta_{i}^{j-1}} D\Delta\theta}{\theta_{i-1}^{j-1}-\theta_{i}^{j-1}}$$

(d) $$C_{i}^{j-1/2} = \left(\frac{\partial\theta est}{\partial h}\right)_{i}$$

evaluated at $\theta est = \left(\theta_{i}^{j} - \theta_{i}^{j-1}\right) \times 0.7 + \theta_{i}^{j}$

(e) Compute h_{i}^{j} from Equation (10)

(f) Compute new θ_{i}^{j} from the corresponding h_{i}^{j}

To implement the above procedure, Equation (10) is written in matrix form with all terms multiplying h_{i}^{j} on the left and the terms multiplying h_{i}^{j-1} and the gravity terms on the right. The resulting matrix on the left is tridiagonal and can be inverted by Gauss elimination. There remains only the requirement for initial and boundary conditions.

Initial conditions of θ for all depths are specified by the modeller or are based upon his knowledge of soil conditions at the start of the simulation time period. The effect of improperly specifying the initial soil moisture profile is a complex function of the soil type, evapotranspiration model, and nature of the first storm. Generally, if the simulation is not started on the day of a big storm, little or no impact will result if the evapotranspiration model is functioning properly. Usually a period of dry soil can be picked to facilitate the choice of initial θs. If the last profile is available from the simulation output it can be used to restart the simulation.

Figure 64 shows a representative soil column used for solving Equation (10) as outlined above. The top layer is the rainfall and runoff layer and ordinarily should have an initial value of zero, i.e., no standing water.

The depth of the soil profile, NEND-1, is a simulation parameter which determines where water transfer to lower zone storage occurs. Water reaching this layer is transferred to lower zone storage immediately. Thus the value of θ at the lower boundary does not change with time.

Equation (10) contains two terms on the right hand side. The first term represents the movement of water between the soil layer immediately above the i^{th} layer (i-1) and the i^{th} layer itself. The second term represents the movement of water between the i^{th} layer and the layer immediately below (i + 1). For i = 2, i.e., the first soil layer, the boundary condition is specified by setting the first term equal to zero. Thus water is not allowed to move into the top layer during a time step Δt via any interaction between the i = 1 and i = 2 layers. Instead the amount of rainfall during Δt is inserted before the time solution to Equation (10) is determined. In effect this will allow a small amount of water to move into the 2nd soil layer during Δt. The error is not significant because Δt is small.

At the lower boundary, water is not permitted to move during Δt between the i = NEND layer and the NEND + 1 layer. That is, the second term on the right side of Equation (10) for

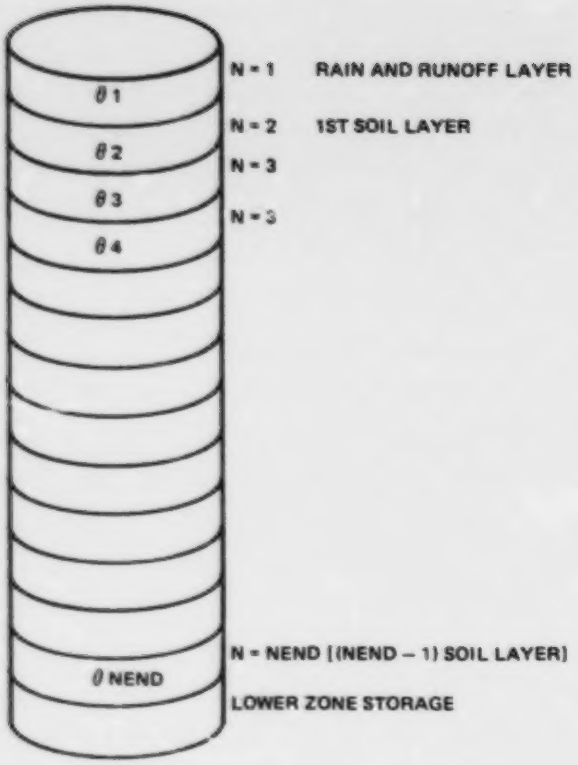

N = 1
RAIN AND RUNOFF LAYER
θ1
N = 2
1ST SOIL LAYER
θ2
N = 3
θ3
N = 3
θ4
N = NEND [(NEND – 1) SOIL LAYER]
θ NEND
LOWER ZONE STORAGE

Figure 64. Representative soil column for water movement and storage.

i = NEND is set equal to zero. However, water does not build up in this layer because any water which enters the layer is transferred to lower zone storage.

Sensitivity Analysis of WATER Submodel

Three storms were selected from the 1973 (P-01) data to use while testing the infiltration submodel sensitivity. Strictly speaking, it is not necessary to use actual storms, but the sensitivity of the submodel should be tested within the range of actual rainfall rates. In addition, the results of the sensitivity runs can also be used to set parameters for the final simulation if the actual storm data is used. Table 8 summarizes the rainfall data for the three storms selected.

The first event (May 28, 1973) represents a relatively short storm of high intensity over the entire period. The second event (September 9, 1973) is of moderate intensity over a longer period and exhibits two peak rainfall rates. The third event (December 31, 1973) is a low intensity storm over a long period with a short peak rainfall rate.

Table 8. RAINFALL CHARACTERISTICS FOR THREE STORMS IN 1973

Storm	Total Rain	Duration	1st Hour	Peak Rainfall Rate	Peak Duration
May 28, 1973	5.4 cm	85 min	4.2 cm	0.14 cm/min	5 min
September 9, 1973	4.1 cm	138 min	2.4 cm	0.12 cm/min	5 min (twice)
December 31, 1973	5.0 cm	490 min	0.5 cm	0.233 cm/min	3 min

Sensitivity to Rainfall Characteristics by Soil Type

A soil type is defined by a unique set of soil diffusivity values and moisture potential values as a function of soil moisture content. Hydraulic conductivity is calculated from the tables of diffusivity and moisture potential as discussed above. Representative values of pressure head and diffusivity are shown in Figures 65 and 66.

Four soil types were tested for each of the storms: (1) Geary Silt Loam,[26] (2) Sarpy Loam,[26] (3) Light Clay,[27] and (4) Cecil Sand.[28] Sensitivity to soil type is illustrated by comparing the runoff hydrographs for each soil type for a given storm (Figures 67, 68, and 69).

Initial moisture content was taken as dry (θ between 0.06 and 0.07) throughout the soil profile. The results are not surprising. Clay produces the most runoff and exhibits the greatest sensitivity to rainfall rate. Geary produces runoff but considerably less than Clay. Sarpy and Cecil produce little or no runoff. Table 9 summarizes the results and presents the measured values for watershed P-01.

Detailed comparisons between the actual and simulated data are not appropriate because the initial moisture profile was arbitrarily selected. However, the absence of any runoff is significant for the first two storms because the choice of initial moisture content is realistic.

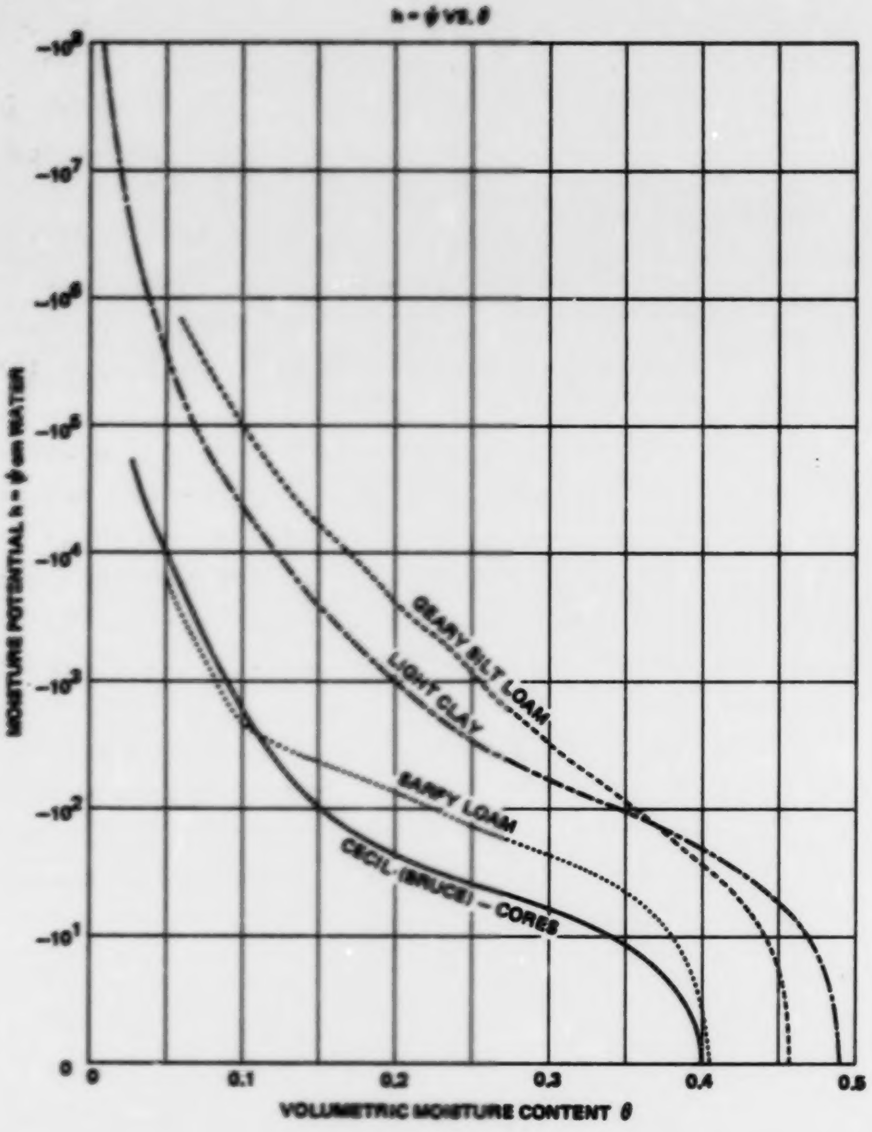


Figure 65. Moisture potential for selected soil types

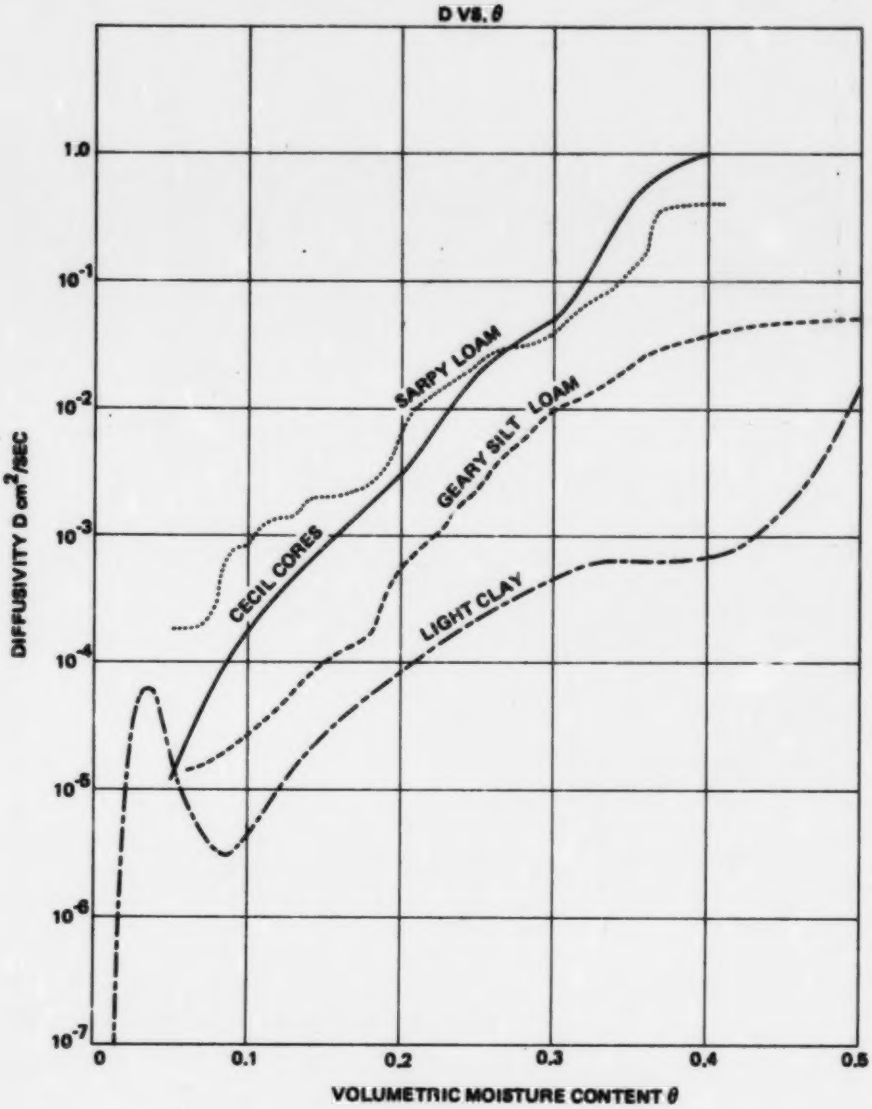


Figure 66. Diffusivity for selected soil types

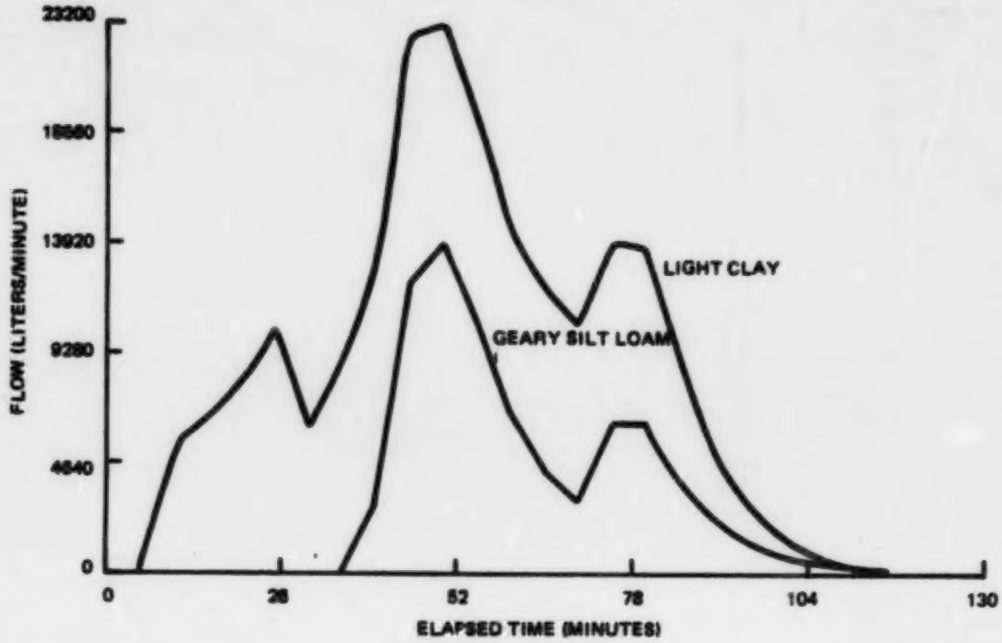


Figure 67. P-01 Watershed: WATER model sensitivity to soil type for May 28, 1973, storm

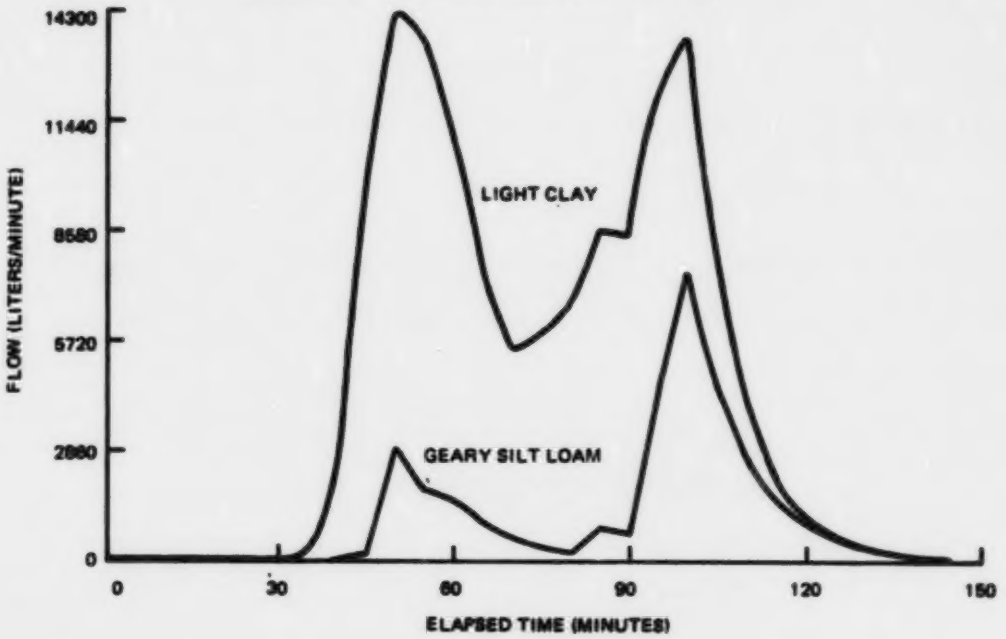


Figure 68. P-01 Watershed: WATER model sensitivity to soil type for September 9, 1973, storm

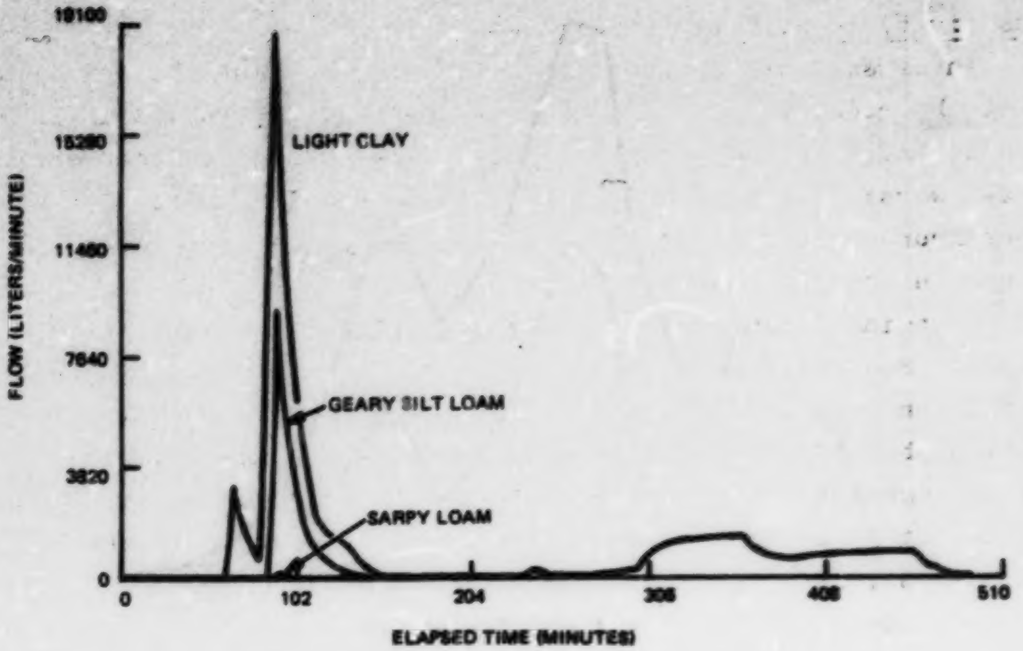


Figure 69. P-01 Watershed: WATER model sensitivity to soil type for December 31, 1973, storm

Table 9. RUNOFF VOLUME (LITERS) BY SOIL TYPE

	Runoff Volume in Liters				
Storm Date	Actual	Clay	Geary	Sarpy/Cecil	
May 28, 1973	803,670	1,033,785	383,614	-	-
September 9, 1973	400,461	720,416	174,123	-	-
December 31, 1973	475,000	583,054	129,711	2703	-

Sensitivity to Soil Layer Thickness

Three sets of computer runs were made to test the sensitivity of the model to the thickness of the soil layers (ΔZ in Equation 10 and G in the computer code). The impact of G can show up in two ways; (1) an indirect effect via the treatment of the upper boundary condition, and (2) an indirect effect via a change in the simulation time step.

Changing G produces a significant effect on the simulated runoff. For Clay, as G increases from 0.5 to 2.0 cm. the total runoff tends to decrease except for the December 31, 1973, storm (Table 10). Runoff is decreased for the May 28, 1973, and September 9, 1973, storms because of the effect on the boundary condition at the surface. The apparent anomaly in the December 31, 1973, storm is caused by an indirect effect via the lower boundary condition and should be ignored (see Figures 70 to 72).

Table 10. RUNOFF VOLUME (LITERS) AS A FUNCTION OF SOIL LAYER THICKNESS FOR CLAY SOIL

	Runoff volume in Liters		
Storm Date	G=0.5 cm	G=1.0 cm	G=2.0 cm
May 28, 1973	1,052,675	1,033,785	946,027
September 9, 1973	720,015	706,416	633,107
December 31, 1973	403,710	538,054	470,544

A slightly different effect was observed when the model was tested for Geary Soil (Table 11, Figures 73 to 75). Water moves through the soil profile rapidly for Geary and the corresponding sensitivity runs actually demonstrate the effect of the lower boundary condition. For a fixed number of soil layers, water is

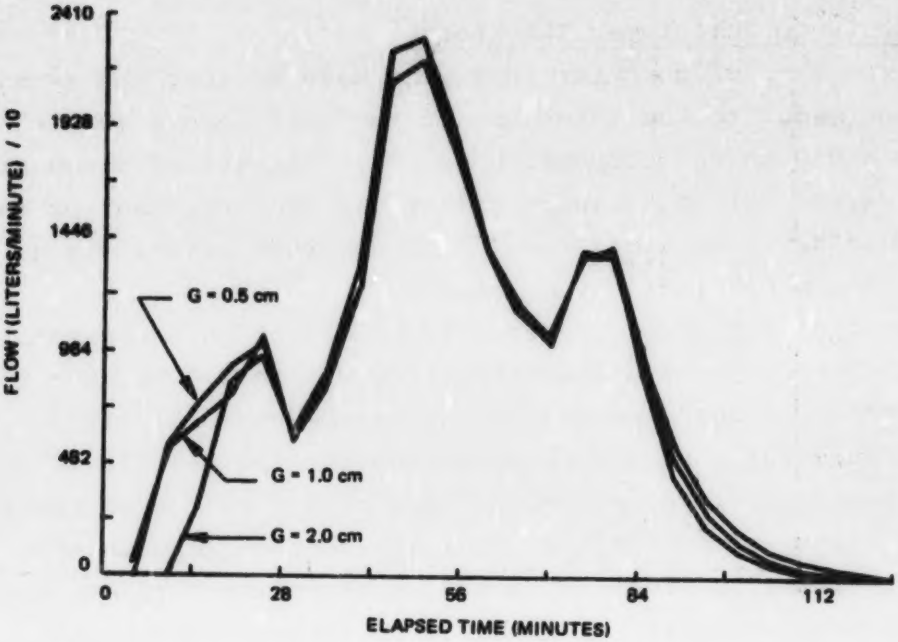


Figure 70. WATER model sensitivity to soil layer thickness (G) for Clay soil (May 28, 1973, storm)

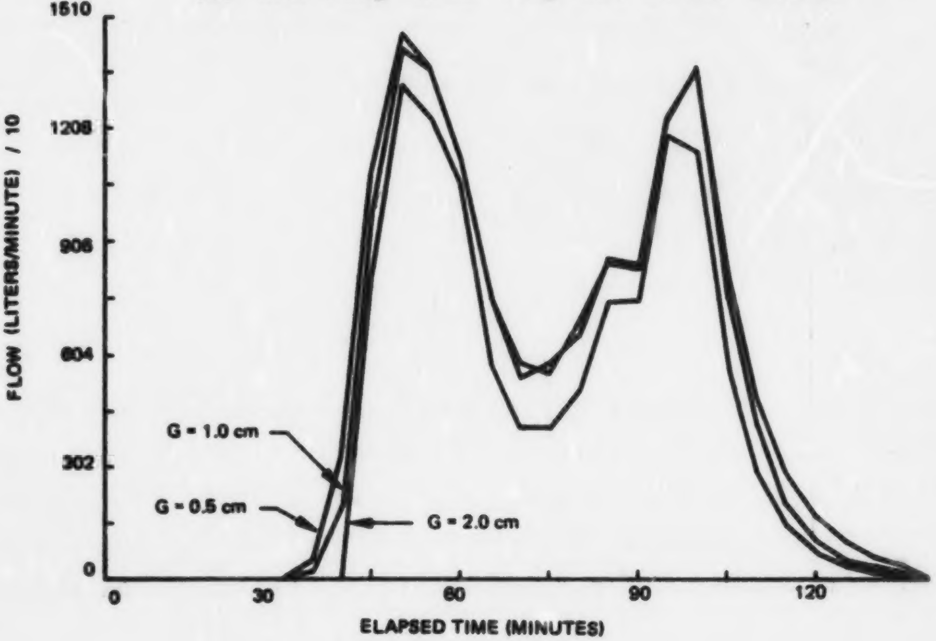


Figure 71. WATER model sensitivity to soil layer thickness (G) for Clay soil (September 9, 1973, storm)

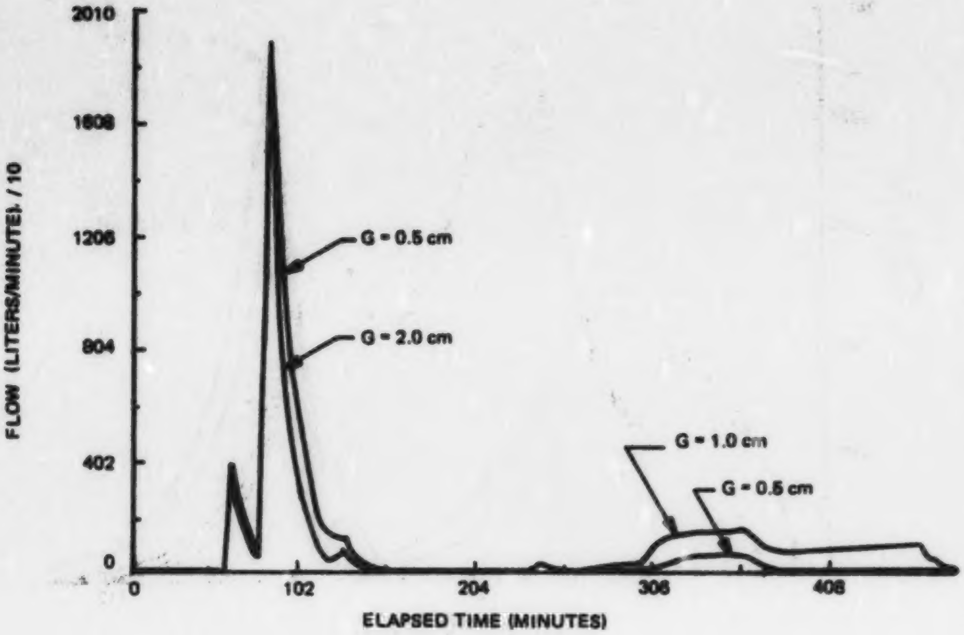


Figure 72. WATER model sensitivity to soil layer thickness (G) for Clay soil (December 31, 1973, storm)

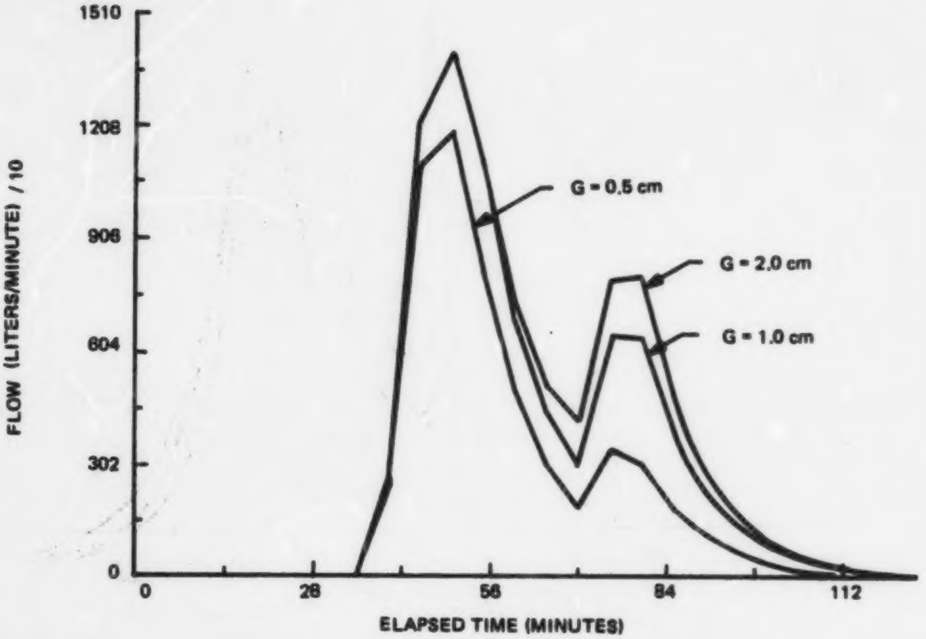


Figure 73. WATER model sensitivity to soil layer thickness (G) for Geary soil (May 28, 1973, storm)

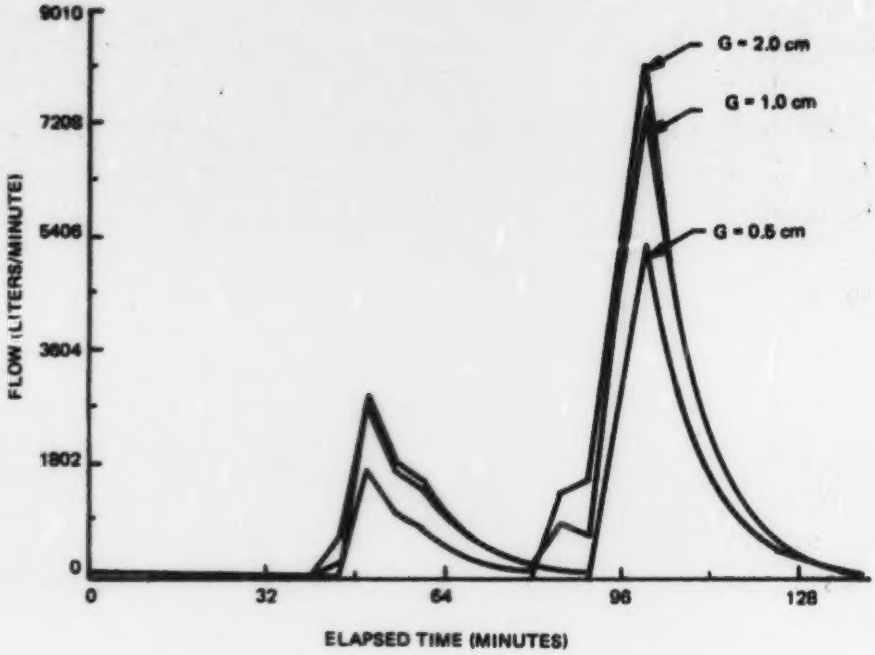


Figure 74. WATER model sensitivity to soil layer thickness (G) for Geary soil (September 9, 1973, storm)

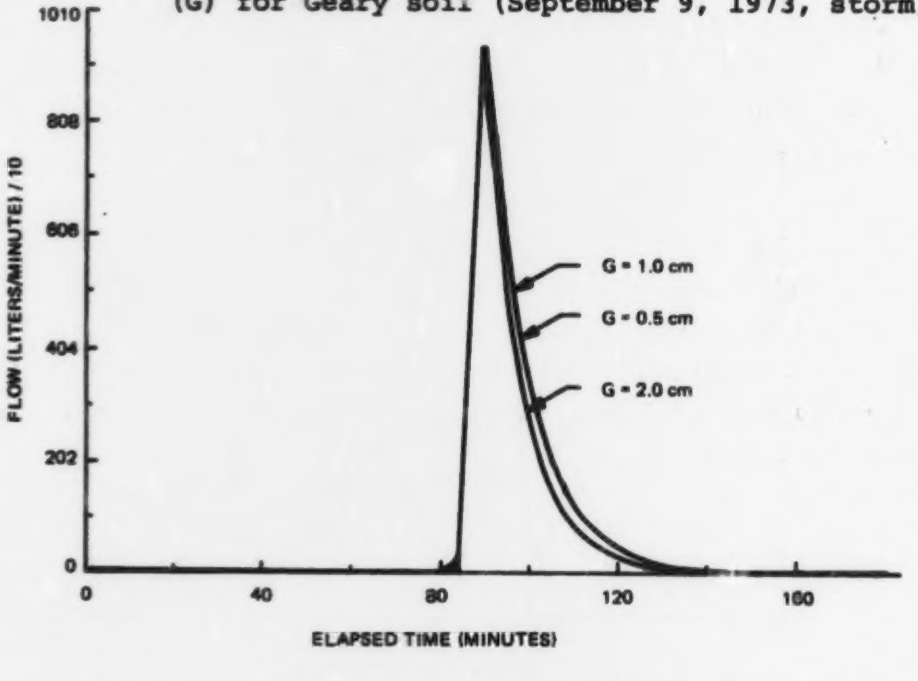


Figure 75. WATER model sensitivity to soil layer thickness (G) for Geary soil (December 31, 1973, storm)

removed and transferred to lower zone storage more rapidly as G decreases. Hence, for short duration storms runoff increased as G increases, but for a long duration storm (December 31, 1973) this effect is nullified and the runoff decreased as the soil layer thickness increases.

Table 11. RUNOFF VOLUME (LITERS) AS A FUNCTION OF SOIL LAYER THICKNESS FOR GEARY SOIL

Storm	Runoff Volume in Liters		
Date	G=0.5 cm	G=1.0 cm	G=2.0 cm
May 28, 1973	269,746	383,614	419,806
September 9, 1973	126,719	174,123	164,165
December 31, 1973	132,176	129,711	119,592

In summary, as G increased from 0.5 to 2.0 cm, the runoff decreases due to the effect on the upper boundary condition. For soils with high infiltration rates, G should be set at or above 2.0 cm and NEND should be 15-20. Soils with low infiltration, like Clay, will be very sensitive to G and numbers less than 1.0 cm should be specified.

Sensitivity to Initial Moisture Content

The significance of the initial moisture content on the runoff hydrograph will depend on the soil type. Soils which exhibit high infiltration and percolation rates will not exhibit much sensitivity to the initial soil moisture profile (assuming the soil is not saturated).

Sensitivity to initial moisture profile was tested for each of the three storms using Clay and Geary soils. Dry ($\theta = 0.06$), moist ($\theta = 0.20$), and wet ($\theta = 0.35$) soil profiles were tested.

Figures 76 to 78 show the effect on the runoff hydrograph for Clay. Similar less dramatic changes were observed for Geary soil in Figures 79 to 81.

For both the May 28, 1973, and September 9, 1973, storms, the runoff volume for Clay increased approximately 10 percent when θ was changed from 0.06 to 0.20 and increased another 12 percent when θ was changed from 0.20 to 0.35. The effect was more significant for the December 31, 1973, storm because of the high intensity rainfall that occurred.

These results suggest that the runoff hydrograph is not particularly sensitive to the initial soil moisture profile unless there is a period of high intensity rainfall.

Specification of Boundary Conditions

The boundary conditions must be specified in order to solve Equation (10). That is, the modeller must supply values for h^i_j, $h^j_{NEND + 1}$ and $\theta^j_{NEND + 1}$.

Infiltration from a flooded surface may be represented by having h^j_i set to zero. This situation may occur at some time during the storm, but it would not be true generally during the early part of the storm. Accordingly, more water would be infiltrated during a short time step than the amount that actually fell on the ground. An adjustment would have to be made after each time step to correct the water in the first soil layer in a manner which is consistent with the rainfall rate during that period. It would also follow that if the flooded infiltration rate were less than the rainfall rate, runoff would occur regardless of the moisture content of the first soil layer.

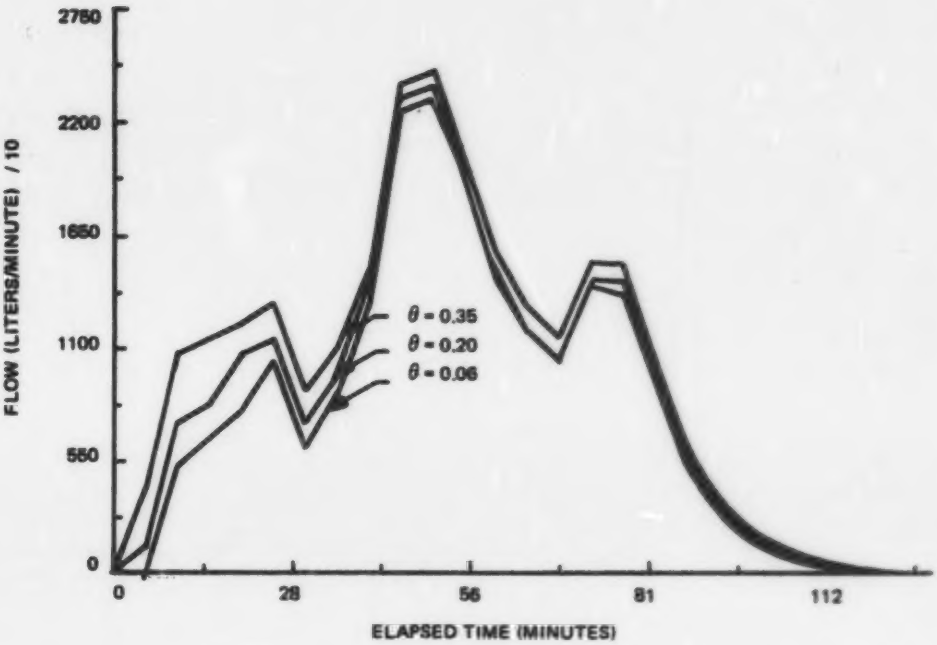


Figure 76. WATER model sensitivity to initial soil moisture for Clay soil (May 28, 1973, storm)

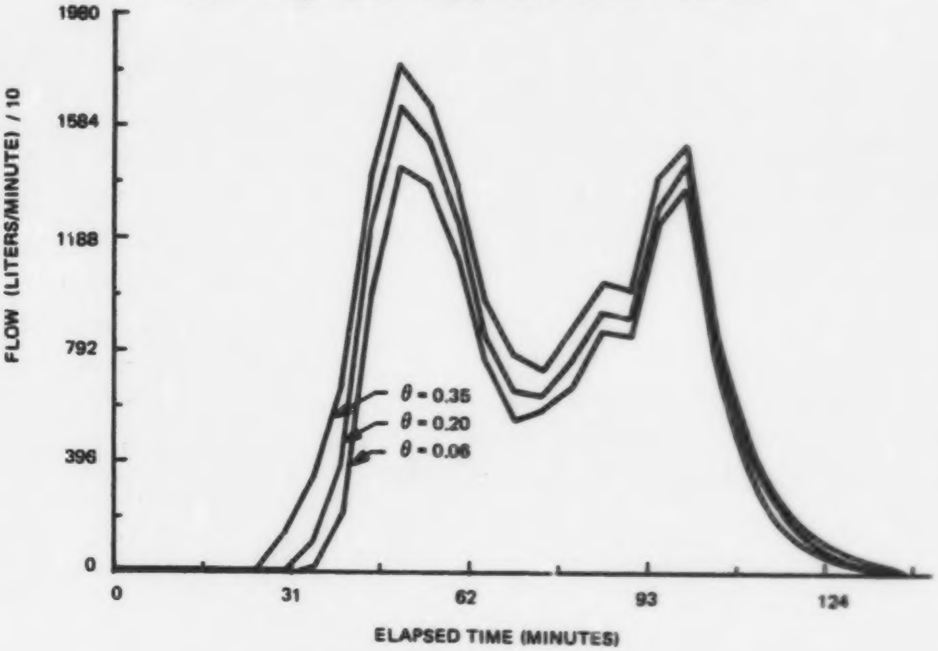


Figure 77. WATER model sensitivity to initial soil moisture content for Clay soil (September 9, 1973, storm)

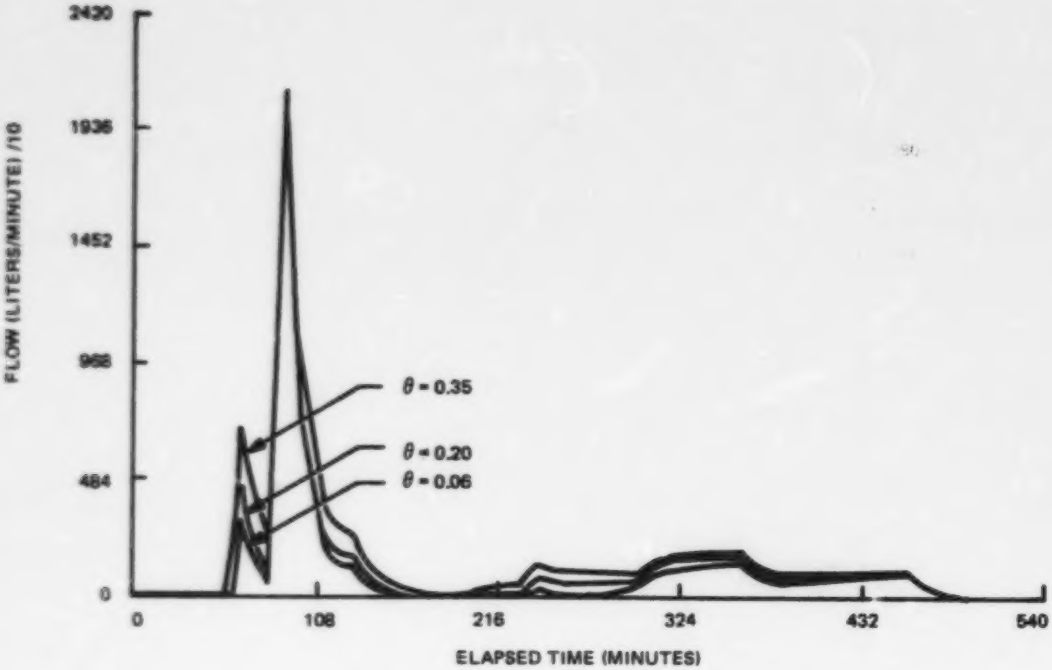


Figure 78. WATER model sensitivity to initial soil moisture for Clay soil (December 31, 1973, storm)

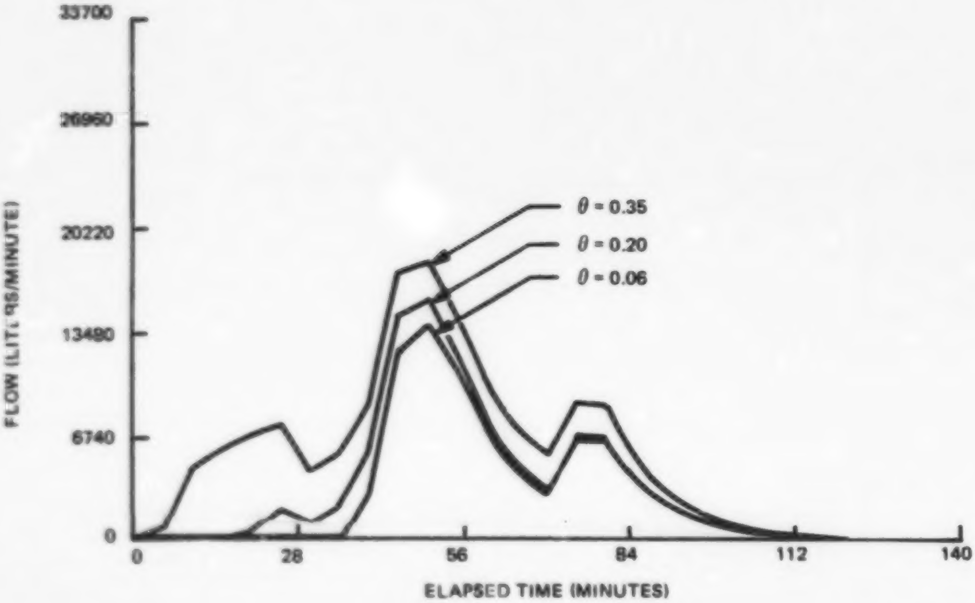


Figure 79. WATER model sensitivity to initial soil moisture for Geary soil (May 28, 1973, storm)

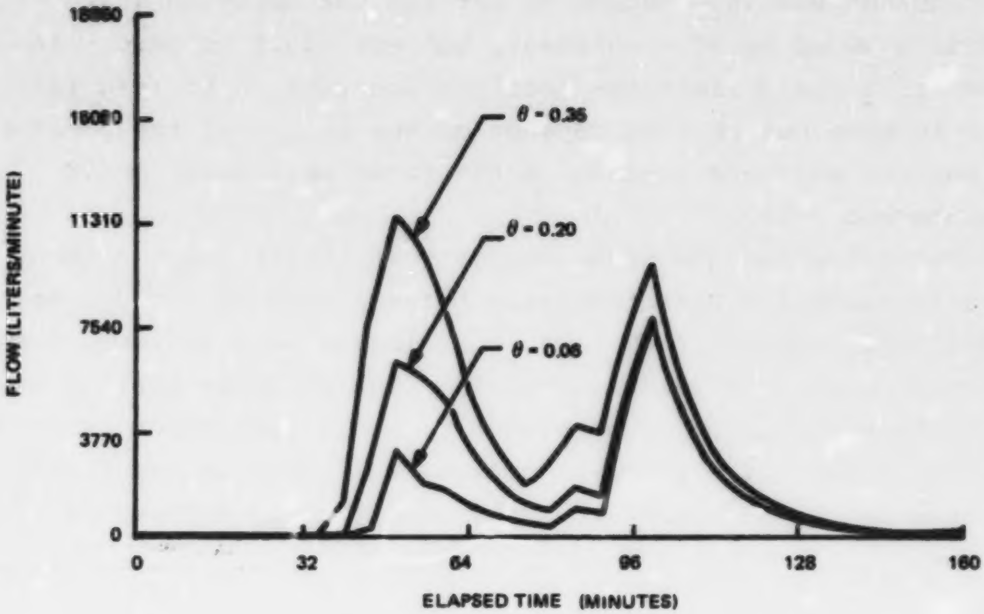


Figure 80. WATER model sensitivity to initial soil moisture for Geary soil (September 9, 1973, storm)

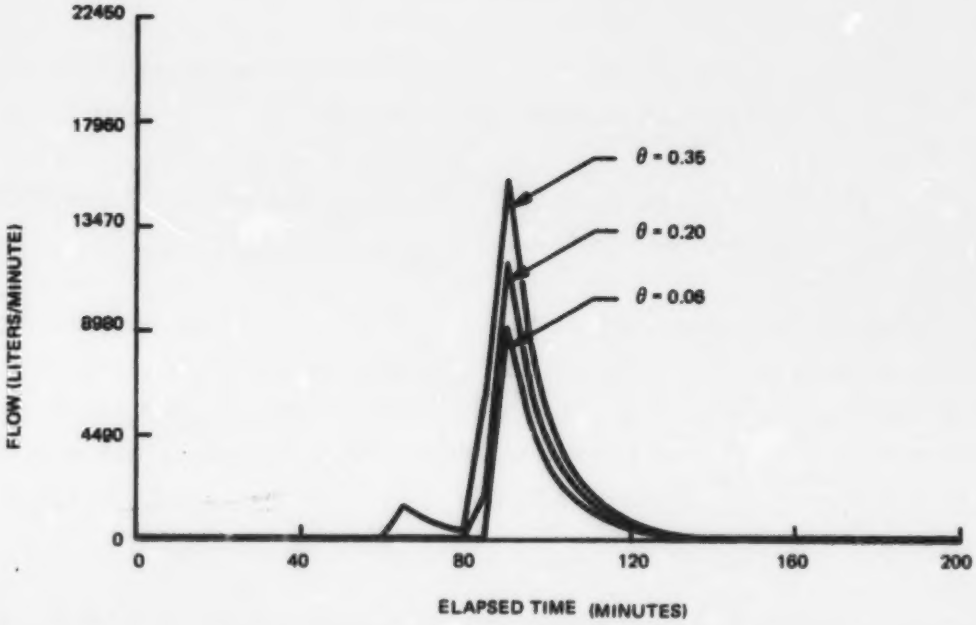


Figure 81. WATER model sensitivity to initial soil moisture for Geary soil (December 31, 1973, storm)

Another possible method of setting the upper boundary condition would be h_1^j = constant, but not equal to zero. In effect this would limit the infiltration rate to be less than or equal to some number that depends on the choice of the constant. The maximum moisture content of the first soil layer could never exceed $\theta(h_1^j)$.

For selecting the upper boundary condition, each method above is basically unsatisfactory because they do not correspond to realistic expectations. During rainfall on a soil where the moisture content is below saturation, the moisture content at the surface should build up gradually until saturation is reached or until the rainfall ceases, whichever occurs first. For this reason the upper boundary condition is defined as follows:

(1) For a small time interval (≤ 1 minute) calculate the rainfall that would occur

(2) Add the rainfall to the first soil layer

(3) If the first soil layer exceeds saturation, the excess is runoff

(4) Solve Equation (10) without letting any additional water infiltrate.

Actually, the simulation structure is more complex, since any zone within the watershed may contain water which has run off in the previous time step. Step (1) therefore includes any water on the surface from the previous time step which has not run off, in addition to that water which has run onto a zone from another zone.

As a result, the specification of the upper boundary condition is fixed by the constraint that the infiltrated water must be less than or equal to the total rainfall at a given time. The excess of rainfall over cumulative infiltration is runoff for each zone.

At the lower boundary the situation is different. For soils which have high infiltration and percolation rates, the water can easily move 10-20 cm into the soil during a storm of moderate duration. Once the wetting front has reached another soil horizon with lower permeability the water will back up, reducing the infiltration rate.

Using Geary Silt Loam as a test case, percolated water was allowed to build up in the "NEND" layer. For the May 28, 1973, storm this condition generates 519,546 liters of runoff. This can be compared to a boundary condition of transferring any water that reaches the "NEND" layer to lower zone storage which produces 383,614 liters of runoff.

If "NEND" is set large enough the water will not penetrate to the bottom layer during the rainfall event. Using this condition the simulated runoff was 419,806 liters. This approach is satisfactory if the choice of NEND does not require going below the next soil horizon.

Another possibility would be to let the soil moisture content build up to a specified level and then remain constant by transferring water to the lower zone storage. This approach increases runoff as the specified level is increased until the 519,546 liter figure is reached.

Based upon the results discussed above, the lower boundary condition is specified to minimize the impact on runoff. NEND is set between 15 and 20. When a soil layer thickness is 1.0 cm, water generally will not infiltrate to this depth during a typical storm. Water that does reach this point, either during the storm or during subsequent percolation, is transferred to lower zone storage. This will produce some runoff error in the long duration storms but it should not be significant over a one year period.

SEDIMENT TRANSPORT SUBMODEL (SED) AND SENSITIVITY ANALYSES

The SCRAM simulation structure requires a microscopic description of sediment yield for the upland phase of the soil erosion process. The upland phase is closely related to the individual precipitation events and the mechanics of these events are important in determining the actual yield.

Generally, upland erosion is categorized as either rill or interrill erosion. In rill erosion the runoff on an erodible soil surface concentrates into many well defined small irregular channels called rills. The erosion occurring on the area between the rills is called interrill erosion.

For these areas the erosive agents are rainfall and runoff. Consequently, the mechanics of sediment removal and transport are describable by four different processes:

(1) detachment by rainfall (raindrop impact)
(2) transport by rainfall (raindrop splash)
(3) detachment by runoff
(4) transport by runoff.

Factors which must be considered in describing the yield from these processes include:

(1) Soil properties - soil type, texture, tilth, soil moisture content, permeability, compactness, and infiltration capacity. These conditions influence the amount of runoff and the soil behavior when subjected to rainfall impact and moving water.

(2) Vegetation properties - type of vegetation, primarily as it effects the amount of rain reaching the ground and the kinetic energy of the rainfall reaching the ground.

(3) Topographic properties - slope, slope length, average width.

(4) Human influencing properties - agricultural practices.

(5) Meteorological properties - primarily the amount, duration, and intensity of rainfall.

It is a difficult task to assemble a mathematical model at the micro-level which includes all of the variables and parameters and describes the physics of the transport. Part of the difficulty is in describing the intricate relationships involved and in being able to quantify and measure values needed in order to complete the description.

A search of the literature revealed several incomplete but likely candidates. These models included stochastic sediment yield models,[29,30] models using kinematic wave theory (continuity and dynamic equations),[31] conceptual models for computer simulation,[32] and models such as the Foster-Meyer[34,35,40] which combines conceptual techniques with fundamental continuity equations.

The Foster-Meyer model was selected for use in SCRAM because it incorporates parameters which are available to or generated during the simulation. Conversely, the model has not been tested against field data and consequently the model parameters have not been developed or related to measurable soil properties and characteristics. Some of these difficulties were overcome with the assistance of Mr. Foster.[33]

Foster-Meyer Sediment Model

The development of the Foster-Meyer (F-M) sediment model starts with the basic continuity-of-mass transport equation:

$$D_F + D_i = \frac{\partial G_F}{\partial x} \tag{11}$$

where D_F = rill flow detachment (deposition) rate at a location (wt/unit area/time)

D_i = delivery rate of detached particles from interrill areas to the rill flow (wt/unit area/time)

G_F = sediment load of the flow at any location on a slope; weight transport rate (wt/unit width/time)

Deposition is viewed as the negative of detachment.

G_F is the independent variable of interest. To determine values for it, an interrelationship equation is used involving flow detachment and the weight transport rate:

$$\frac{D_F}{D_C} + \frac{G_F}{T_C} = 1 \qquad (12)$$

where D_C = detachment capability of the rill flow at a location (weight/unit area/time)

T_C = flow transport capability at a location (weight/unit width/time)

Foster and Meyer[34] caution that Equation (12) above has not been experimentally verified, however, Bennett,[36] Foster and Meyer[35] present a qualitative argument for its usage.

As for the other terms needed to solve for G_F, Foster and Meyer[34,35] cite empirical evidence as a basis for assuming that both D_C and T_C are proportional to a power of the bottom sheer stress ($D_C \propto \tau^{3/2}$, $T_C \propto \tau^{3/2}$, where τ is the tractive force or bottom sheer stress). On the basis of empirical evidence, the D_i term in Equation (11) has been shown to be approximately proportional to the square of the rainfall intensity ($D_1 \propto I^2$, where I is the rainfall intensity.)

Except for the evaluating coefficients and proportionality constants involved in the terms above, Equations (11) and (12) can be solved given knowledge of the rainfall conditions and the overland flow.

Sediment Model Output

The Foster-Meyer model predicts the following quantities:

(1) Sediment load at any location on the slope (weight/unit area/time) and total sediment "yield" at the bottom of the slope.

(2) Detachment/deposition rate at any location on the slope (weight/unit area/time).

(3) Deposition and sediment load decay beyond the end of the slope (weight/unit area/time).

Derivation of Working Equations

For convenience the equations describing the processes being modeled (11) and (12) are repeated here as a single equation.

$$\left.\begin{aligned} \frac{\partial G_F}{\partial_X} &= D_F + D_i \\ \frac{D_F}{D_C} &= \frac{G_F}{T_C} = 1 \end{aligned}\right\} \qquad (13)$$

Initial conditions at the top of the slope are assumed known or determinable.

The solution of Equation (13) parallels that of Foster and Meyer[34,35] and employs the following notation:

let L = length of the slope (reference)
X = distance from the top (down the flow)
D_{CO} = detachment capacity at the bottom of the slope
T_{CO} = transport capacity at the bottom of the slope
X_* = X/L so that $0 \leq X_* \leq 1$

See Figure 82.

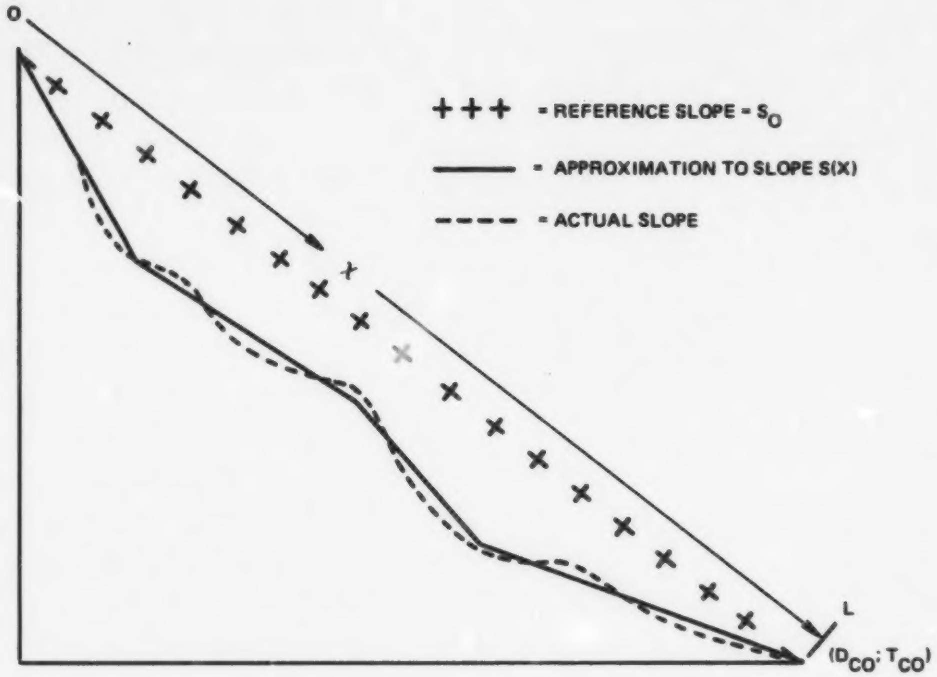

O
+++ = REFERENCE SLOPE = S_O
—— = APPROXIMATION TO SLOPE S(X)
---- = ACTUAL SLOPE
X
L
$(D_{CO}; T_{CO})$

Figure 82. Schematic of upland area used to develop Foster-Meyer sediment model

Next, define non dimensional detachment capacity as:

$$g_* = \frac{D_C}{D_{CO}} = \frac{C_D X_* S}{C_D(1) S_O} = X_* S_* \tag{14}$$

$$= \frac{T_C}{T_{CO}} = \frac{C_T X_* S}{C_T(1) S_O} = X_* S_* \tag{15}$$

where C_O = Coefficient of flow detachment capacity and $C_D(1)$ refers to the bottom of the slope.

C_T = Coefficient of flow transport capacity and $C_T(1)$ is the corresponding term at the bottom of the slope.

S_* = S/S_O = Relative slope along a land profile.

Next set:

$\theta = \frac{LD_i}{T_{CO}}$ (a measure of the T_{CO} that is filled by interrill rainfall detachment and transport)

and $\alpha = \frac{LD_{CO}}{T_{CO}}$ (a measure of the flow's capacity to detach a certain soil),

substituting into Equation (13) and reducing:

$$\left.\begin{aligned} &\frac{\left(d\ D_F/D_{CO}\right)}{dX_*} + \left(D_F/D_{CO}\right) = \left(\frac{dg_*}{dX_*} - \theta\right) \\ &\frac{G_F}{T_{CO}} = g_* - D_F/D_{CO} \end{aligned}\right\} \qquad (16)$$

Solution for a Constant Slope

For a single uniform slope, $S(X) = S_O$, and making the reasonable assumption that D_i = constant, we can integrate Equation (16) to give:

$$\frac{D_F(X_*)}{D_{CO}} = \left(\frac{1-\theta}{\alpha}\right)\left(1-e^{-\alpha X_*}\right) + C\ e^{-\alpha X_*} \qquad (17)$$

where C is a constant of integration and must be evaluated by initial conditions, viz., perhaps $D_F(0) = 0$, and

$$\frac{G_F(X_*)}{T_{CO}} = X_* - \frac{D_F(X_*)}{D_{CO}} \qquad (18)$$

Solution for the general case -

Assuming it is possible to "come straight down the slope" as depicted in Figure 82, the general solution is derived as follows:

let S_O = reference slope

S_j = slope of the jth increment; $j = 1$ at the top let $K_j = S_{*j} = S_j/S_O$ for the j^{th} interval; then

$$\frac{D_F^{(j)}(X_*)}{D_{CO}} = \frac{(K_j - \theta)}{\alpha}\left[1 - e^{-\alpha X_*}\right] + C_j e^{-\alpha X_*} \tag{19}$$

and

$$\frac{G_F^{(j)}(X_*)}{T_{CO}} = K_j X_* - \frac{D_F^{(j)}(X_*)}{D_{CO}} \tag{20}$$

where X_* is now relative to the jth interval

Evaluation of the integration constant C_j

For the top interval, the initial conditions at the top of the slope are needed as before, viz., $D_F(1)(0) = 0$. Once having gotten started, C_j has the form

$$C_j = \left\{ \left(\frac{D_F{}^{j-1}(X_{*\mu})}{D_{CO}}\right) - \left(\frac{K_j - \theta}{\alpha}\right)\left(1-e^{-\alpha X_{*\mu}}\right)\right\} e^{\alpha X_{*\mu}} \tag{21}$$

where $X_{*\mu}$ is at the upper end of the j^{th} increment or the lower end of the $j-1^{st}$.

Also note that the following condition must hold:

$$\frac{D_F{}^{(j)}(X_{*\mu})}{D_{CO}} = K_j X_{*\mu} - \frac{G_F{}^{(j)}(X_{*\mu})}{T_{CO}} \tag{22}$$

Equation (21) however allows D_F to be continuous as the transition is made from the (j-1) to the (j) interval. In practice, we first maintain the continuity of the sediment load.

$$G_F^{(j)}(X_{*\mu}) = G_F^{(j-1)}(X_{*\mu}) \tag{23}$$

and from Equation (20)

$$\frac{D_F^{(j)}(X_{*\mu})}{D_{CO}} = K_j X_{*\mu} - \frac{G_F^{(j-1)}(X_{*\mu})}{T_{CO}} \tag{24}$$

Substitution into Equation (19) produces the new C_j.

However, if $D_F(X_{*\mu})$ is negative, deposition is occurring. In this case, if the slope increment is long enough, deposition may cease and erosion may reoccur at a lower position.

The equations describing deposition are:

$$\frac{D_F^{(j)}(X_*)}{D_{CO}} = \frac{K_j}{\alpha}\left[1 - e^{-\alpha X_*}\right] + \tilde{C}_j e^{-\alpha X_*} \tag{25}$$

$$\frac{G_F(X_*)}{T_{CO}} = K_j X_* - \frac{D_F^{(j)}(X_*)}{D_{CO}} \tag{26}$$

for $X_* \geq X_{*\mu}$

$X_* \varepsilon j^{th}$ interval

where $$\tilde{C}_j = \left\{ \frac{D_F^{(j-1)}(X_{*\mu})}{D_{CO}} - \frac{K_j}{j} \left[1 - e^{-\alpha X_{*\mu}}\right] \right\} e^{\alpha X_{*\mu}} \tag{27}$$

Also, since $D_F = 0$ where deposition ends, say, at X_e, solve for X_e to give

$$X_e = \frac{1}{\alpha} \ell n(K_j - \alpha \tilde{C}_j) - \ell n K_j$$

Therefore, at $X_* = X_e$ compute a new value of C_j:

$$C_j = -\left(\frac{K_j - \theta}{\alpha}\right)\left(1 - e^{-\alpha X_e}\right) e^{\alpha X_e} \tag{28}$$

and proceed for $X_* \geq X_e$.

The procedure to evaluate constants to reduce accumulated error is:

(1) Evaluate constants at each slope change

(2) Evaluate constants where $D_F = 0$

(3) Evaluate constants where deposition ends and detachment begins.

Model Parameters

The delivery rate of detached particles from interrill areas to rill flow, D_i, is a required model parameter. In certain situations D_i is assumed constant, e.g., uniform slope and constant rainfall rate. In general, Meyer and Wischmeier[32] have demonstrated that D_i is proportional to the square of rainfall intensity. In particular:

$$D_i = A_i K_3 I^2 \tag{29}$$

where I = rainfall intensity
K_3 = function of the soil type
A_i = area of the increment under observation

This approach has been adapted by ESL for use in the Foster-Meyer Sediment Model.

Estimation of the detachment capacity of the rill flow at a location, D_c, is more complicated. According to Yalin,[37] sediment motion begins when the lift force of the flow exceeds a critical lift force. Once the particles are lifted from the bed, the drag force of the flow carries particles "downstream" until the particle weight forces it out of the flow and back to the bed. The average critical force for a number of agricultural soils[35] appears to be about 1.0 g/cm.

For large tractive forces ($\tau >> 1.0$ g/cm)

$$D_C \propto \tau^{3/2} \tag{30}$$

in general

$$D_c = C_d \ \tau^{3/2} \tag{31}$$

$$T_c = C_t \ \tau^{3/2} \tag{32}$$

where C_t = coefficient depending on particle size and density
C_d = coefficient that is a function of soils resistance to erosion by flow

In the Foster-Meyer model[34,35] the average sheer stress is defined as:

$$\bar{\tau} = \gamma\bar{y}S$$

where γ = density of runoff

S = slope

$\bar{y}$ = average flow depth

and where $\bar{y}$ and S are functions of X.

A more exact expression for bottom sheer stress is:

$$\tau = \gamma R_h S_e$$

where R_h = hydraulic radius

S_e = slope of the energy gradeline

Because of the small flow depths one can assume $S_e = S$ (S is the slope of land profile at X), and assuming turbulent flow, then flow depth = hydraulic radius (since the width of the flow >> depth). Hence the expression

$$\bar{\tau} = \gamma\bar{y}S \tag{33}$$

By the Chezy form of the uniform flow equation[39] the average flow depth at location X is:

$$\bar{y} = \left[\sigma \cdot X \cdot 1 \cdot (8g\ S/f)^{1/2}\right]^{2/3} \tag{34}$$

where σ = excess rainfall rate = (rainfall intensity infiltration rate)

S = slope at X

g = acceleration constant due to gravity

f = Darcy-Weisbach coefficient of friction

The effective tractive force (bottom sheer stress) is then proportional to $\bar{\tau}$.

$$\tau = C_{rp}\bar{\tau} \tag{35}$$

so that

$$D_c = C_d \cdot C_{rp}^{3/2} \cdot \gamma^{3/2} \left(\frac{f}{8g}\right)^{1/2} \cdot S \cdot \sigma \cdot X \tag{36}$$

and

$$T_c = C_t \cdot C_{rp}^{3/2} \cdot \gamma^{3/2} \left(\frac{f}{8g}\right)^{1/2} \cdot S \cdot \sigma \cdot X \tag{37}$$

Slightly different estimates for D_c, T_c can be derived in terms of X_*. As noted by Foster and Meyer,[35] the estimates of D_c and T_c may be modified using discharge rates rather than excess rainfall measures.

$$D_c = C_d(C_{rp}\gamma)^{3/2} \left(\frac{f}{8g}\right)^{1/2} \cdot S \cdot X_* \cdot q_o = C_D S X_* \tag{38}$$

and

$$T_c = C_t(C_{rp}\gamma)^{3/2} \left(\frac{f}{8g}\right)^{1/2} \cdot S \cdot X_* \cdot q_o = C_T S X_* \tag{39}$$

where C_T = coefficient for flow transport
C_D = coefficient for flow detachment
q_o = discharge rate per unit width at the bottom of the slope
$X_* = X/L$

Within the SCRAM simulation structure the average flow depth is generated in the WATER subroutine. Accordingly, we can combine Equations (31), (32), (33), and (35) to write:

$$D_c = C_d(C_{rp}\ \delta\bar{y}S)^{3/2}$$

$$= K_2(\bar{y}S)^{3/2} \tag{40}$$

and

$$T_c = C_t(C_{rp}\delta\bar{y}S)^{3/2}$$

$$= K_1(\bar{y}S)^{3/2} \tag{41}$$

Sediment Model Parameter Estimate

The first parameter of interest is K_3, used in calculating the delivery rate of detached particles from interrill areas to rill flow:

$$D_i = K_3 I^2$$

where I = rainfall intensity.

To obtain "ball park" estimates for K_3, data from Moldenhauer and Long[41] were utilized. The Moldenhauer data were obtained in laboratory experiments and are summarized in Table 12 below; the area of the test "beds" was 1394 cm^2, the units have been changed to the metric system, and the K_3 calculations have been added.

Table 12. EXPERIMENTAL VALUES FOR K_3.

Rainfall Rate	$I = 9.527 \times 10^{-4}$ cm/sec		$I = 18.833 \times 10^{-4}$ cm/sec	
Soil Type	D_i (observed) $g/cm^2/sec$	K_3 Calculated	D_i (observed) $g/cm^2/sec$	K_3 Calculated
1. Liton Silty Clay	1.72×10^{-5}	18.94	4.59×10^{-5}	12.93
2. Marshall Silty Clay Loam	1.43×10^{-5}	15.75	3.2×10^{-5}	9.0
3. Ida Silt	5.02×10^{-6}	5.5	2.25×10^{-5}	6.34
4. Kenyon Loam	9.54×10^{-6}	10.5	2.3×10^{-5}	6.48
5. Hagens Fine Sand	-	-	2.55×10^{-5}	7.18

The proposed relationship is not exactly satisfied for the Moldenhauer data, but it does suggest a range for K_3 between 7 and 20.

Similarly, if we use the data from Foster and Meyer[34,35] shown in Table 13, a range for K_3 between 15 and 20 is derived.

As noted above, the detachment capacity $D_C = K_2 (\bar{y}S)^{3/2}$ and the transport capacity $T_C = K_1 (\bar{y}S)^{3/2}$, where $\bar{y}$ is the average flow depth at location X and S is the profile slope at X.

Ranges for K_1 and K_2 were estimated from the Foster-Meyer data in Table 13. T_{CO} was calculated from $\theta = LD_i/T_{CO}$ with L = 35 feet. Then D_{CO} was determined from the relation $\alpha = L\, D_{CO}/T_{CO}$.

Table 13. PREDICTED VALUES OF SEDIMENT LOAD FROM FOSTER AND MEYER[34,35]

Case	α	θ	$\frac{G_F^{(1)}}{T_{CO}}$	D_i tons/acre/hr	Soil Loss Predicted tons/acre/hr	Measured tons/acre/hr
1.	.046	057	0784	10.0	13.7	11.5
2.	.250	.029	.1409	7.7	37.2	29.0
3.	.065	.043	.0734	7.7	12.3	10.9

The calculated values for T_{CO} were 1.164, 1.762, and 1.188 g/cm/sec for the three cases shown in Table 13. Corresponding values for D_{CO} were 5.025×10^{-5}, 4.127×10^{-4}, and 7.23×10^{-5} g/cm^2/sec.

Apparently, Table 13 contains an error because the program predicted the same values for the first two cases, but predicted 13.14 tons/acre/hour for the third case.

With the above values as representative for T_C and D_C, K_1 was initially estimated to be in the interval (20,300) and K_2 in the interval (8.5×10^{-4}, 8×10^{-2}). The smaller values appear to be better under the steady state and uniform rainfall excess assumptions.

Based upon the results and the sensitivity analysis in the next section, a suitable range of parameters can be developed for running the simulation.

Sensitivity Analysis of the Sediment Model

The general sensitivity of the sediment model to variations of the several different parameters was checked analytically where possible and also via computer runs to obtain numerical estimates. For the analytical determinations the solution for the sediment load reduced to its most basic form is:

$$G_F(X_*) = (K_1 C_1) \left\{ X_* - \frac{\left(1 - L \frac{K_3}{K_1} \frac{I^2}{C_1}\right)}{L \frac{K_2}{K_1}} \cdot 1 - e^{-L \frac{K_2}{K_1} X_*} \right\} \quad (42)$$

where $C_1 = (\delta \bar{y}(1)\ S)^{3/2}$

and the other notation is as used previously. (Note that $\delta = 1$.) This form is used and discussed further below.

For the computer checkout the following inputs, with their assigned values shown, were used for tests. Except for length and width of the slope, which remained constant throughout the testing, each of the inputs were allowed to vary while all others remained fixed.

Length	405 m
Width	670 m
Slope	.0375(3.75%)
Average Runoff Depth	.5 cm
Rainfall Intensity	.1 cm/min
K_3 (Soil Type Constant)	8.
K_1	20.
K_2	$1. \times 10^{-3}$

These values of length, width, and slope were chosen to approximate the dimensions of the P-01 watershed. Average runoff depth and rainfall intensity values were chosen after studying rainfall data on P-01 as reasonable values during a storm. The values chosen for K_3, K_1, and K_2 are discussed in the previous section.

Sensitivity to slope -

A plot of sediment load vs slope of the watershed is shown in Figure 83. Slope was allowed to vary from 1% to 30%. The model is not very sensitive to changes in slope in the ranges of interest although, as expected, sediment load always increases as slope increases.

From Equation (42) above, the sediment load for only S variable has the form $G_F = N_1S^{3/2} + N_2$, where the Ns are constants. This increasing function has the form noted in the figure.

Sensitivity to rainfall intensity -

Figure 84 shows that the model is relatively sensitive to rainfall intensity. As expected, sediment load is always an increasing function of rainfall intensity. The curve is not linear, as the rainfall intensity term is squared in the model equations. Analytically, for only I variable the sediment load has the general form $G_F = A + BI^2$.

If I = 0, i.e., rainfall has stopped, then

$$G_F(X_*) = (K_1C_1)\left[X_* - \left(\frac{K_1}{K_2L}\right)\left(1 - e^{-L\frac{K_2X_*}{K_1}}\right)\right] \tag{43}$$

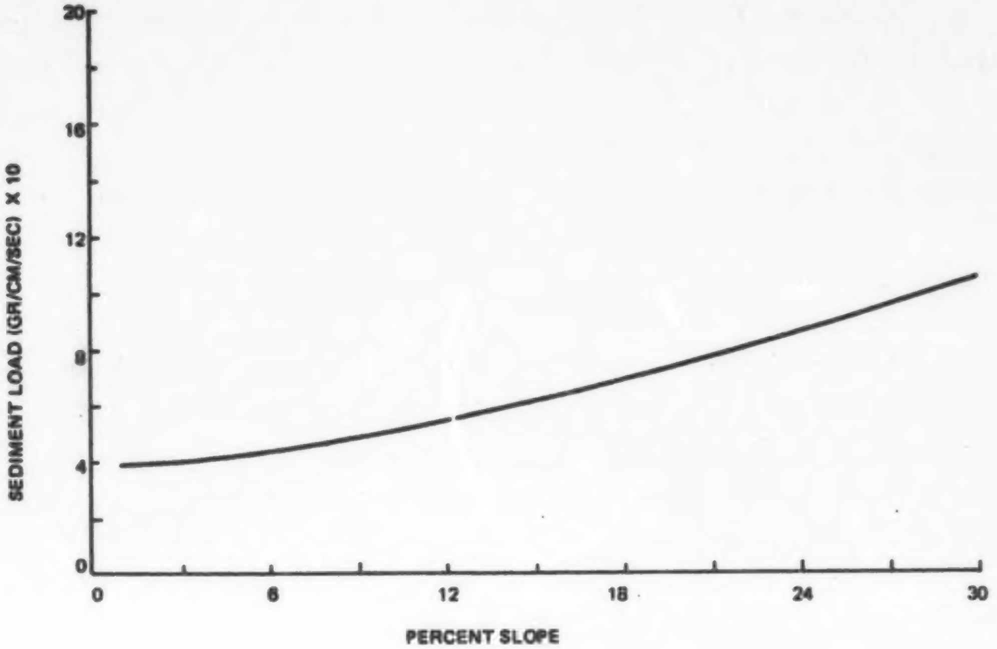


Figure 83. Sensitivity of sediment load to slope

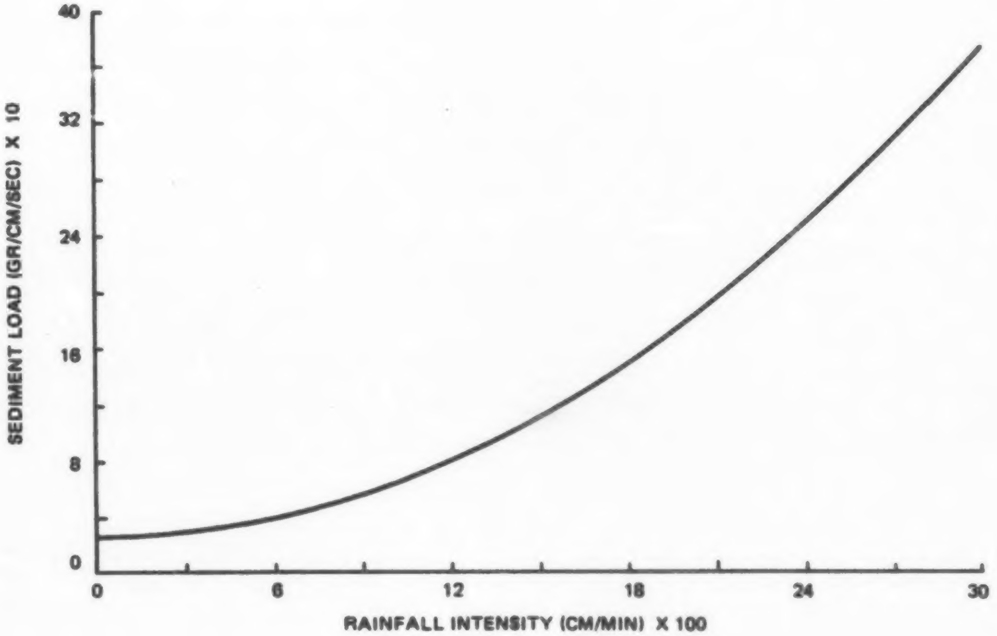


Figure 84. Sensitivity of sediment load to rainfall intensity

where $C_1 = \left(\delta \bar{y}_{(1)}{}^{S}\right)^{\frac{3}{2}}$

therefore: unless S = slope = 0, sediment load decreases continuously until $\bar{y}$, the average depth, reaches zero.

Sensitivity to position on the slope

In Figure 85, sediment load was computed at 100 points on the slope, beginning near the top and moving downward to the bottom of the slope. This test was made primarily to show that the model behaves reasonably well when the slope is cut into pieces; this is necessary to determine when and if a new constant of integration needs to be calculated.

Sensitivity to the number of increments down the slope -

In Figure 86 the sediment load was calculated when the slope was divided into 1, 10, 50, and 100 equal area segments. If the slope is divided into n equal area segments, the computer model checks n times to see if it is necessary to calculate a new constant of integration. The plot in Figure 86 shows that sediment load remains constant, regardless of the value of n, at least for the given input conditions.

Sensitivity to rainfall detachment parameter K_3 -

Using Equation (42), it is easy to show that $G_F = A + BK_3$ for all parameters except K_3 constant. B is always greater than zero, and hence G_F is a linear increasing function of K_3. This relationship is verified by the computer analysis shown in Figure 87 where K_3 was allowed to vary between 1 and 24.

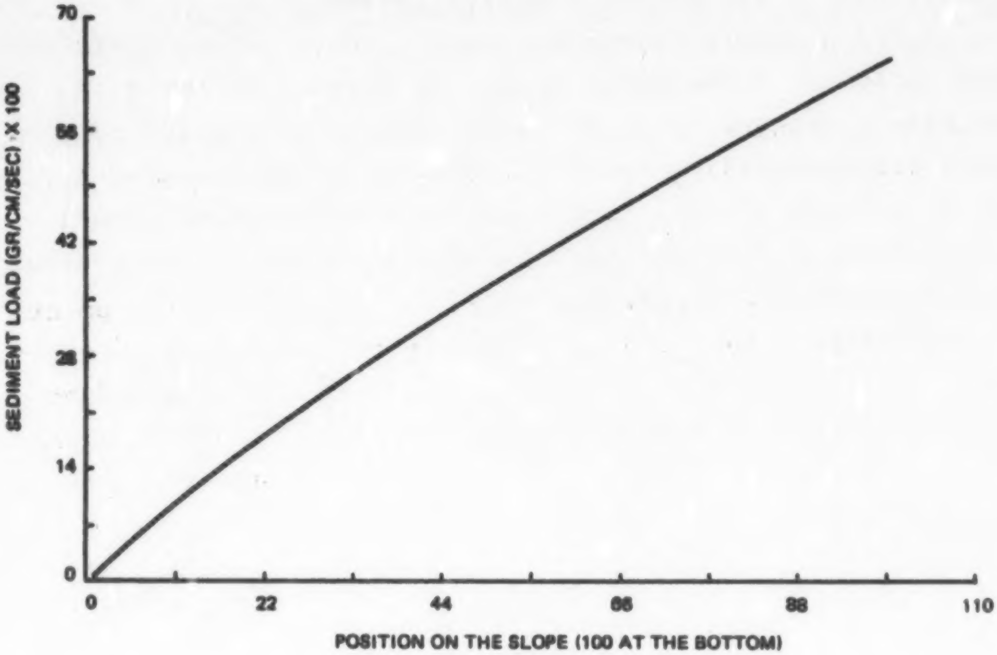


Figure 85. Sensitivity of sediment load to length of the slope

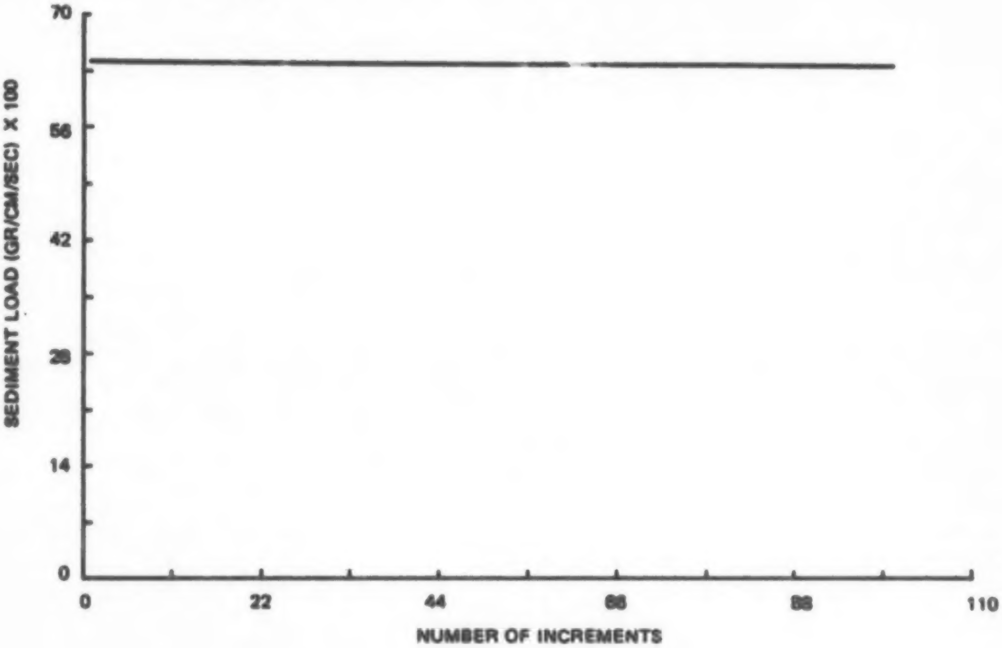


Figure 86. Sensitivity of sediment load to the number of subdivisions down the slope

Sensitivity to detachment capacity parameter K_2 -

K_2 is a complex parameter used to help estimate the detachment capacity of the water flow. As previously noted, K_2 includes a measure of a soil's resistance to erosion by flow and a proportionality constant obtained by calculating the tractive force of this flow from the average sheer stress.

For fixed X_*, and only allowing K_2 to vary, the sediment load function can be written as:

$$G_F(X_*) = K_1C_1X_* - \frac{K_1{}^2C_1(1-\theta)}{L} \cdot \left(\frac{1 - e^{-\left(L\frac{X_*}{X_1}\right) K_2}}{K_2} \right) \qquad (44)$$

so that

$$\frac{\partial G_F}{\partial K_2} = - \frac{K_1{}^2C_1(1-\theta)}{L} \left\{ \frac{W\ K_2e^{-WK_2} - \left(1-e^{-WK_2}\right)}{K_2{}^2} \right\} \qquad (45)$$

where $\quad W = \frac{LX_*}{K_1} \geq 0$

and $\quad WK_2e^{-WK_2} + e^{-WK_2} - 1 \leq 0.$

For $\quad 0 \leq \theta \leq 1, \ \frac{\partial G_F}{\partial K_2} \geq 0$

and hence G_F is an increasing function of K_2;

for $\quad \theta > 1, \ \frac{\partial G_F}{\partial K_2} < 0$ and hence G_F is a decreasing function of K_2.

Figure 88 shows sediment load is K_2 for four different values of K_1. The function is increasing for values of K_1 which make $\theta<1$, and decreasing for values of K_1 which make $\theta>1$. The physically meaningful values seem to occur for the case $0 \leq \theta \leq 1$.

Sensitivity to the transport capacity parameter K_1 -

K_1 is a parameter used to help estimate the transport capacity of the water flow. As previously noted, K_1 is a complex parameter which is a function of soil particle size and density and includes a proportionality constant relating average sheer stress to the tractive force of the flow.

An analytical expression for the sensitivity of G_F to K_1 is difficult to develop but G_F is an increasing function of this parameter.

Figure 89 shows sediment load as a function of K_1. Four curves were plotted, each with a different value of K_2 (constant associated with detachment capacity). All four of the curves intersect where $\theta = 1$. (See model description.) The sensitivity of the model to K_1 shows a marked dependency on the value of K_2 because the ratio K_2/K_1 appears in the equation for G_F.

For the special case of $\theta = 1$, $G_F = K_1 C_1 X_* = K_1 (\bar{y}\ S)^{3/2}$ and so all of the curves will intersect.

Sensitivity to average runoff depth -

With all other coefficients remaining fixed (except $\bar{y}$), the sediment load equation has the form:

$$G_F(X_*) = K_2 \bar{y}^{3/2} \left[X_* - \left(K_1 - K_3 \cdot \frac{1}{\bar{y}^{3/2}} \right) \left(K_4 \right) \right] \qquad (46)$$

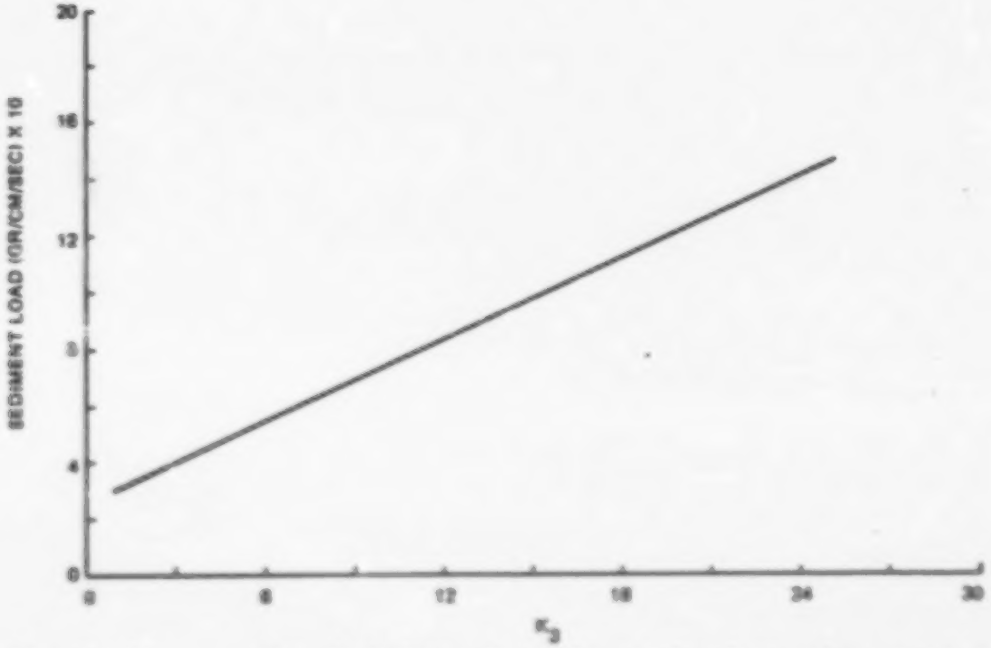


Figure 87. Sensitivity of sediment load to the constant, K_3 = ST associated with rainfall detachment

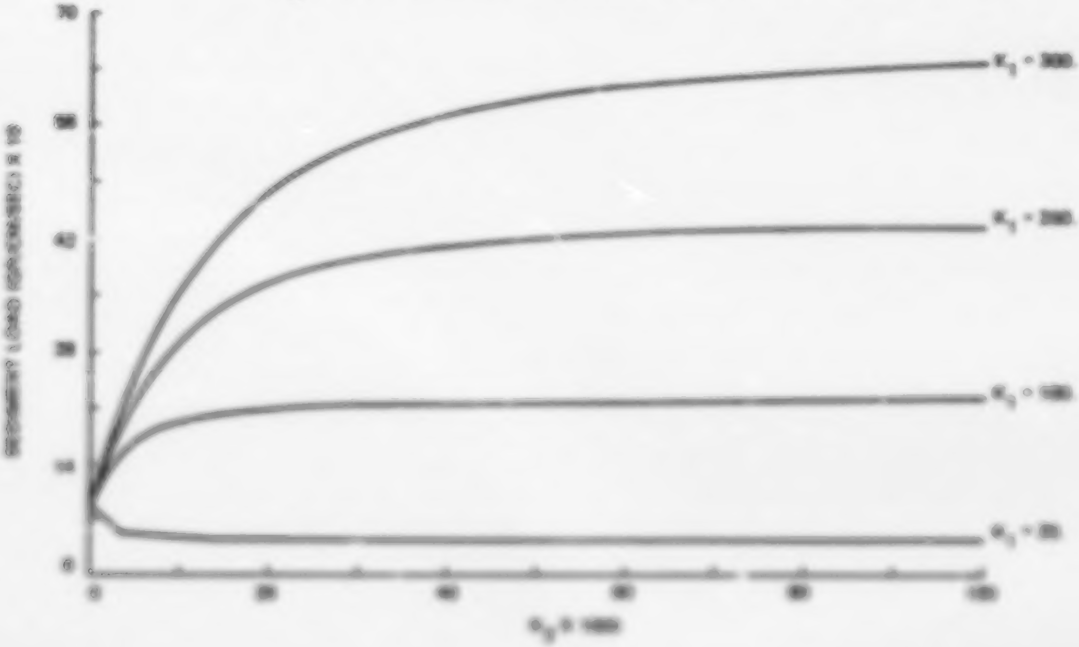


Figure 88. Sensitivity of sediment load to the constant, K_2 associated with rill flow detachment capability

it is easy to show that

$$\frac{\partial G_F}{\partial \bar{y}} = \frac{K_1 S^{3/2}}{L\left(\frac{K^2}{K_1}\right)} \left[\left\{ L\left(\frac{K_2}{K_1}\right) X_* - \left(1-e^{-L\left(\frac{K_2}{K_1}\right) X_*}\right)\right\} 3/2\bar{y}^{1/2} \right] \geq 0$$

hence G_F is an increasing function of $\bar{y}$.

It can be seen in Figure 90, where sediment load vs average runoff depth is plotted, that the model is extremely sensitive to runoff depth. In order that actual conditions can be more realistically simulated, it is important to take small time steps to keep the runoff depth low enough to simulate actual conditions.

Sensitivity to vegetation parameters -

As coded for the sensitivity analyses, the sediment model does not directly take into account the particular vegetation or mulch type(s) present on the watershed subplots. Foster and Meyer studied certain aspects of this problem, e.g., measurements with straw and wheat mulch, and suggested that the ratio of the "unmulched" sheer stress of the flow to that of the "mulched" was a constant raised to a power. The constant was the cube of the ratio of the average flow velocity with mulch to that of the unmulched flow - all other conditions being the same.

With no data available on this aspect of the problem, it was decided not to modify the model during the sensitivity tests to try to account for the "vegetation" type parameters.

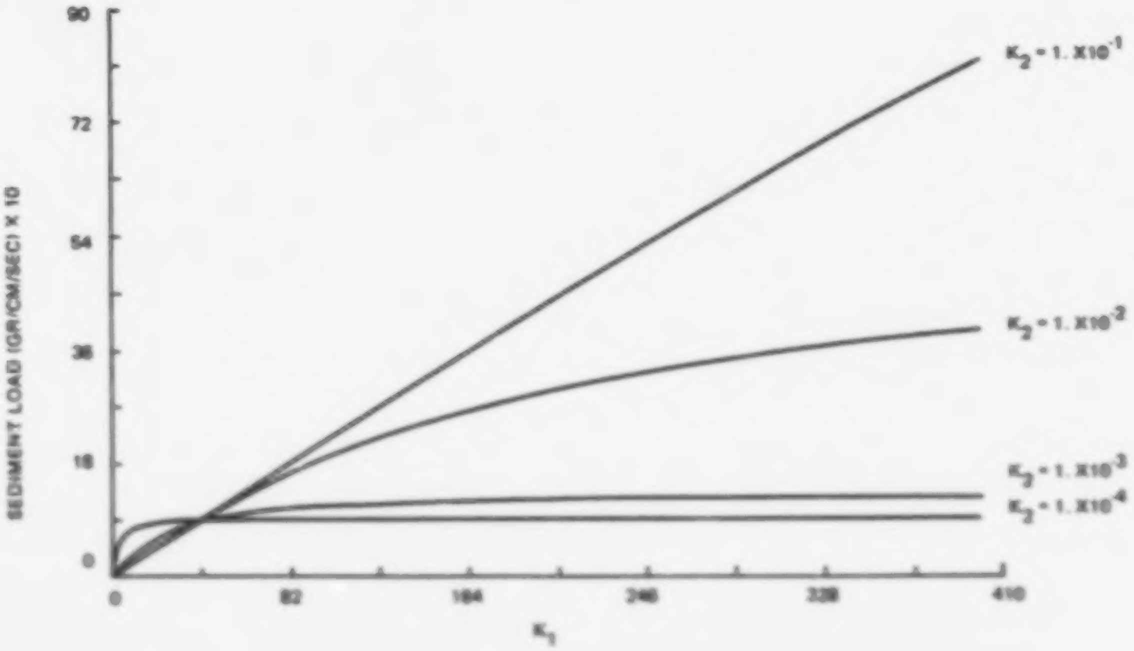


Figure 89. Sensitivity of sediment load to the constant, K_1 associated with transport capacity

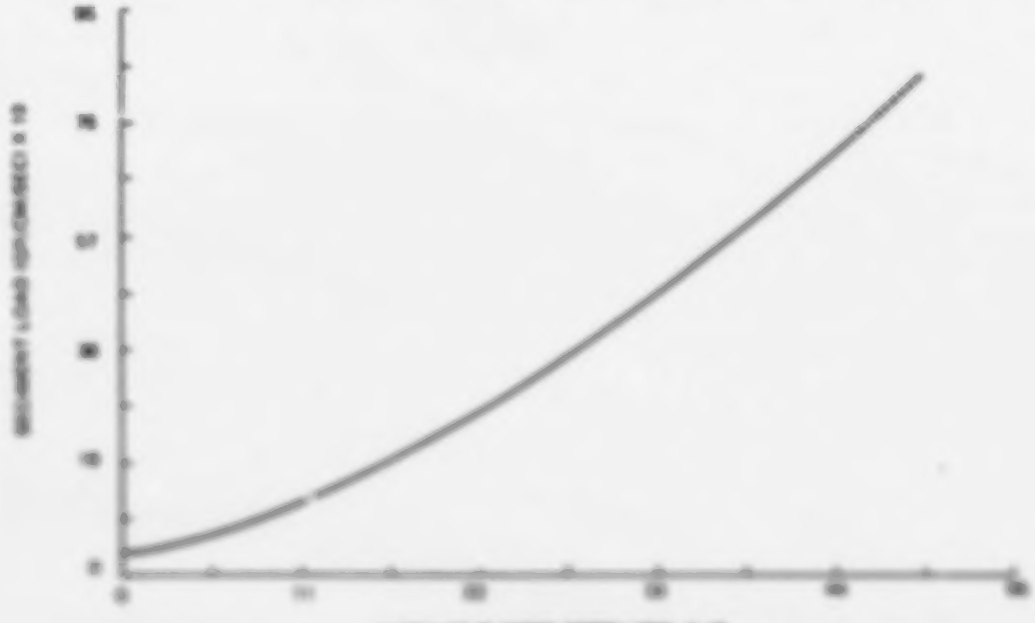


Figure 90. Sensitivity of sediment load to runoff depth

ADSORPTION - DESORPTION SUBMODEL (ADDE) AND SENSITIVITY ANALYSIS

Adsorption and desorption are the controlling processes in the dispersal of pesticide in the soil. Pesticide dispersal is dependent on the chemical properties of the pesticide, the physical characteristics of the soil, the meteorological conditions, and the type and stage of development of the plant cover. Once the chemical properties have been understood and related to the physical soil properties in the adsorption processes, pesticide movement can then be predicted within the range of meteorological events common to the watershed.

Various scientists have studied this problem. Numerous experiments aimed at understanding portions of the adsorption-desorption process have been carried out. Rifai, Kaufman and Todd,[42] Day and Forsythe,[43] Nielsen and Biggar,[44] and Rose and Passioura,[45] studied steady state displacement of water saturated porous material and solutes which do not interact with the solid soil matrix. Likewise, Biggar and Nielsen,[46] Kay and Elrick,[47] and Huggenberger, Letey and Farmer[48] experimented with solutes that are highly adsorbed onto the solid soil matrix. These studies do not address the simultaneous movement of water and solutes that occur naturally.

A modified adsorption-desorption hybrid model developed by Dr. J. M. Davidson[49] was used in the simulation of pesticide adsorption-desorption. Dr. Davidon's model addresses the "combined effect of convection, asorption, and dispersion" with a correction for numerical disperion. Modifications were made to adapt the existing model for use within the simulation structure.

Description of the Adsorption-Desorption Model

The one dimensional transport of solute through soil is described by:

$$\frac{\partial(\theta C)}{\partial t} = \frac{\partial}{\partial Z}\left(\theta D \frac{\partial C}{\partial Z}\right) - \frac{\partial(qC)}{\partial Z} - p\,\frac{\partial S}{\partial t} \qquad (47)$$

where C = solute concentration ($\mu g/cc^3$)

θ = volumetric water content (cc/cc)

t = time (hr)

Z = depth into the soil measured positive in a downward direction (cm)

D = apparent diffusion coefficient (cm^2/hr)

q = volumetric flux of water (cm/hr)

p = soil bulk density (g/cc)

S = adsorbed solute concentration ($\mu g/g$)

The adsorption and desorption processes of Equation (47) are described by the Freundlich equations:

$$S = K_A C^{1/N} \qquad \text{adsorption} \qquad (48)$$

$$S = K_D C^{1/AB} \qquad \text{desorption} \qquad (49)$$

where K_A = adsorption distribution coefficient

K_D = desorption distribution coefficient

N = adsorption exponent constant

AB = desorption exponent constant

Assuming that D is independent of soil depth, and following the Davidson methodology,[49] Equation (47) reduces to:

$$\frac{\partial C}{\partial t} = \frac{D}{W} \frac{\partial^2 C}{\partial Z^2} + \frac{1}{W}\left[\frac{D}{\theta} \frac{\partial \theta}{\partial Z} - \frac{q}{\theta}\right] \frac{\partial C}{\partial Z} \qquad (50)$$

where $W = 1 + \frac{P}{\theta N} K_A C^{1/N-1}$ adsorption (51)

$W = 1 + \frac{P}{\theta AB} K_D C^{1/AB-1}$ desorption (52)

The equations are solved explicitly using a finite difference procedure corrected for numerical dispersion described by Chaudhari (1971).[50]

$$C_i^j = C_i^{j-1} + \frac{\Delta t}{W_i^{j-1} (\Delta Z)^2} (D - Dn_i^j)(C_{i+1}^{j-1} - 2C_i^{j-1} + C_{i-1}^{j-1})$$

$$- \frac{\Delta t}{W_i^{j-1} \Delta Z} (X_i^j - \frac{\Delta t}{2} G_i^j)(C_i^{j-1} \; C_{i-1}^{j-1}) \qquad (53)$$

where $Dn_i^j = 1/2 \left[X_i^j \Delta Z - (X_i^j)^2 \Delta t - G_i^j \frac{\Delta Z \, \Delta t}{2}\right]$ (54)

$$X_i^j = \left(\frac{V}{\theta}\right)_i^j - \left(\frac{D}{\theta}\right)_i^j \frac{\theta_{i+1}^j - \theta_{i-1}^j}{2\Delta Z} \qquad (55)$$

$$G_i^j = \frac{1}{(\theta_i^j)^2} \left[\frac{-(q_i^j)^2}{\theta_i^j} - 2(D_i^j)^2 \left(\frac{\theta_{i+1}^j - 2\theta_i^j + \theta_{i-1}^j}{\Delta Z^2}\right) + 2 D_i^j \left(\frac{q_{i+1}^j - q_{i-1}^j}{2\Delta Z}\right)\right.$$

$$\left. + \frac{(D_i^j)^2}{\theta_i^j} \left(\frac{\theta_{i+1}^j - \theta_{i-1}^j}{2\Delta Z}\right)^2\right] \left(\frac{\theta_{i+1}^j - \theta_{i-1}^j}{2\Delta Z}\right) - 2 \left(\frac{D}{\theta}\right)_i^j \left(\frac{q_{i+1}^j - 2q_i^j + q_{i-1}^j}{\Delta Z^2}\right)$$

$$- \left(\frac{q_i^j - q_i^{j-1}}{\theta_i^j \, \Delta t}\right) \qquad (56)$$

and j = time index

i = spatial depth index

t = time increment

Z = spatial increment

There are a few restrictions in the use of the adsorption-desorption hybrid model. The time increment, Δt, must always satisfy the following criteria:

$$\frac{(D-Dn)\ \Delta t}{\Delta Z^2} \leq 1/2 \tag{57}$$

and

$$\left[\frac{q}{\theta} - \frac{D}{\theta}\ \frac{\partial\theta}{\partial Z}\right] \Delta t \leq 1/4 \tag{58}$$

When associated with an infiltration model that moves water through the soil, the spatial increment, ΔZ, in the solute equation must be an integer multiple of the spatial increment in the water transport equation. This interaction of spatial increments, ΔZ, and time increments, Δt, restricts the results to compatible water models. This restriction is not significant in the SCRAM simulation structure because of the small time increments used in the simulation.

Sensitivity Analyses

Davidson's adsorption-desorption model was tested to determine its sensitivity to variations in the input parameters. Parameters were tested over two time regimes (one hour and five hours of continuous infiltration). The model was most sensitive to layer thickness. Variation of exponent constants, the diffusion coefficient and the conductivity of the pesticide have little effect on the model results.

Sensitivity to layer thickness -

To test the sensitivity of the adsorption-desorption model to variations in soil layer thickness, two soil layer thicknesses, 0.5 cm and 1 cm, were compared for two time periods of continuous infiltration: one hour and five hours. The soil layer thickness affects the depth of pesticide penetration into the soil profile and determines the depth of the maximum-pesticide concentration in solution and adsorbed on the soil.

The solute portion of the pesticide concentration penetrates deeper into the soil profile and the maximum pesticide concentration occurs at a deeper soil depth with the larger soil layer thickness (1 cm) for both the 1 hour and 5 hour time periods. (See Figure 91). The difference in layer thickness dependence of the depth of the maximum pesticide concentration is reduced within five hours.

The adsorbed portion penetrates deeper into the soil profile and a larger portion of the pesticide is adsorbed with 1 cm soil layer thickness. Figure 92 shows the concentrations of the adsorbed pesticide. The relationships between soil layer thickness and adsorbed pesticides exist for both the one hour and five hour time period.

Sensitivity to the adsorption exponent constant -

N is the exponent constant in the Freundlich adsorption equation. Its value is dependent on the pesticide being modelled. Varying N from 1.0 to 9 (the values used for diphenamid and atrazine) produces negligible change in the 1 hour and 5 hour graphs of both the chemical concentration in solution and adsorbed to the soil as seen in Figures 93 and 94.

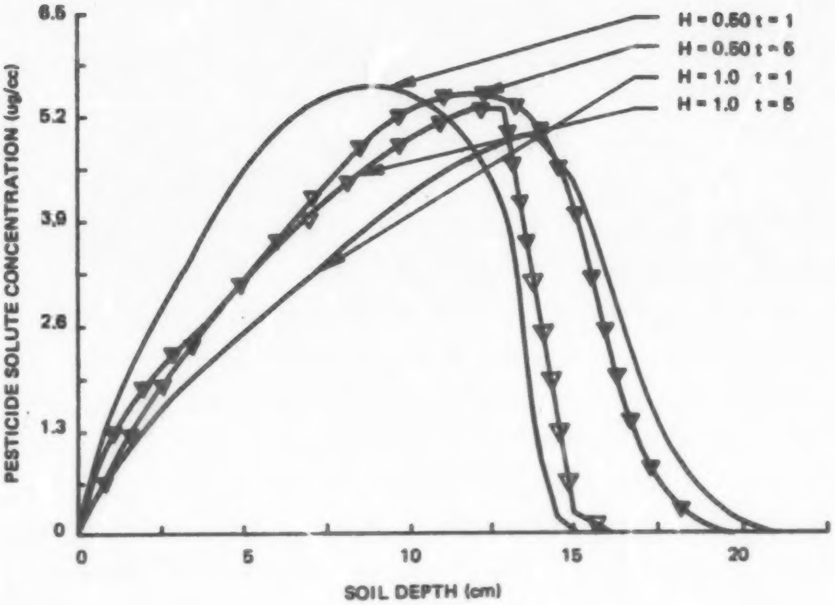


Figure 91. Layer thickness vs solution concentration distribution

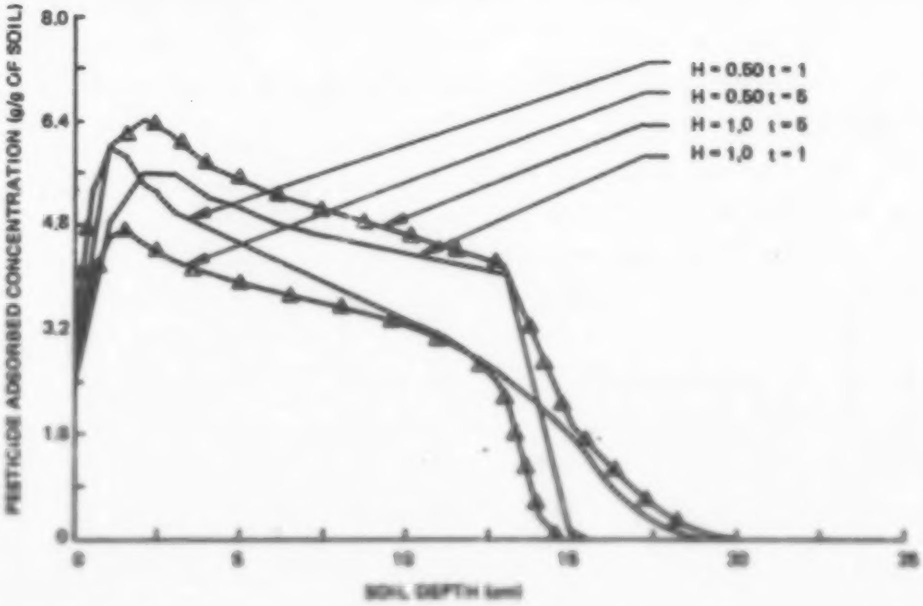


Figure 92. Layer thickness vs adsorbed concentration distribution

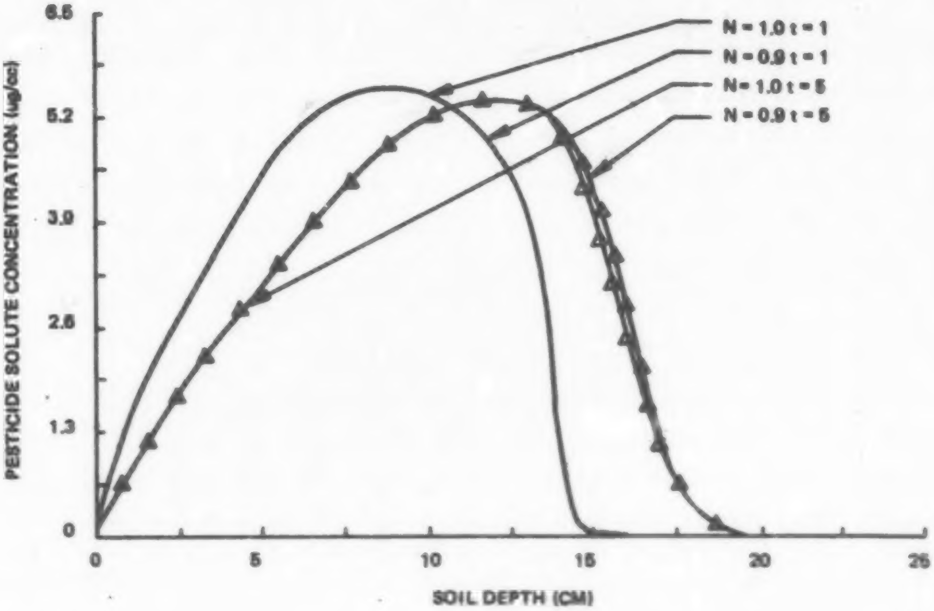


Figure 93. Adsorption exponent vs. solution concentration distribution

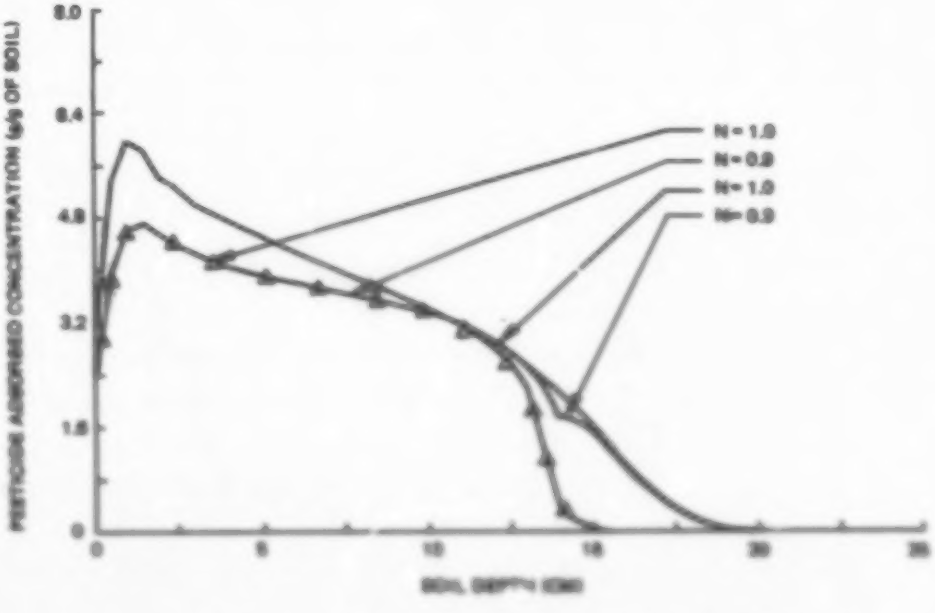


Figure 94 Adsorption exponent vs. adsorbed concentration distribution

Sensitivity to the desorption exponent constant -

AB is an exponent constant associated with desorption in the Freundlich equation. The value assigned to AB is pesticide dependent. AB was varied over a range from 2.5 to 1.7 (the values used for diphenamid and atrazine). As seen in Figures 95 and 96, the adsorbed and solute concentrations show negligible dependence on the value assigned to AB.

Sensitivity to the diffusion coefficient -

D is the apparent diffusion coefficient in the pesticide transport equation. Varying D from .05 to 0.5 does not significantly affect the solution concentration distribution or the adsorbed concentration distribution as seen in Figures 97 and 98.

DEGRADATION SUBMODEL (DEGRAD) AND SENSITIVITY ANALYSES

Degradation of pesticides in the soil is a complex phenomena involving a variety of mechanisms. Among the known mechanisms are chemical, photochemical, and microbial degradation. The quantification of these mechanisms and the effects of environmental factors on the degradation rates of pesticides remains an area of active research.

Most research on degradation has explored the subject under laboratory conditions. These studies have held environmental conditions constant in order to examine specific mechanisms.

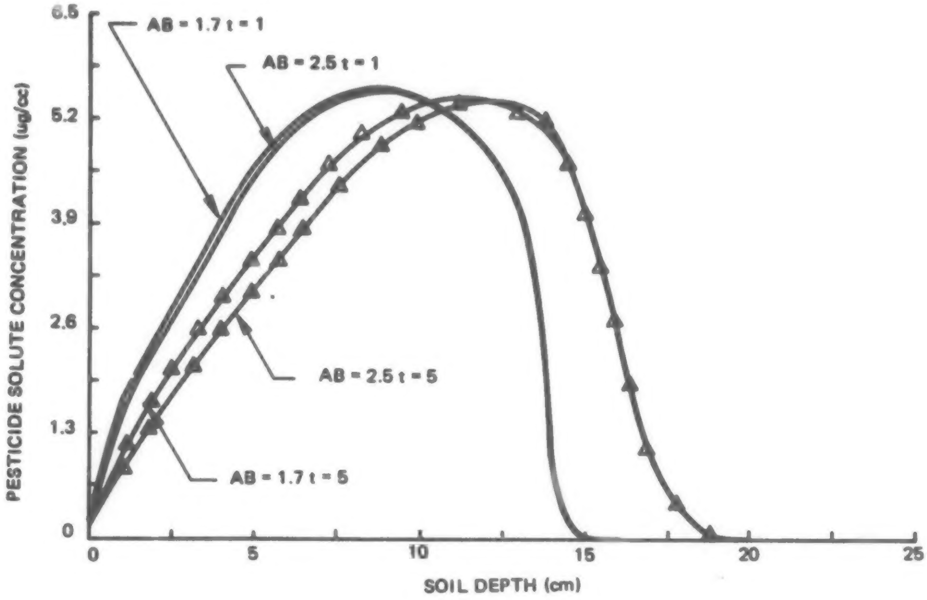


Figure 95. Desorption exponent vs. solution concentration distribution

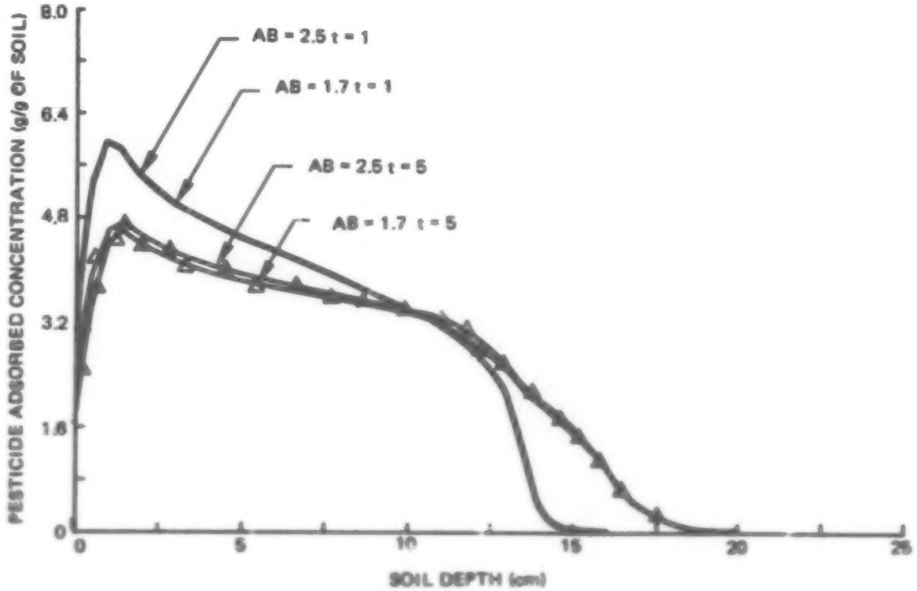


Figure 96. Desorption exponent vs adsorbed concentration distribution

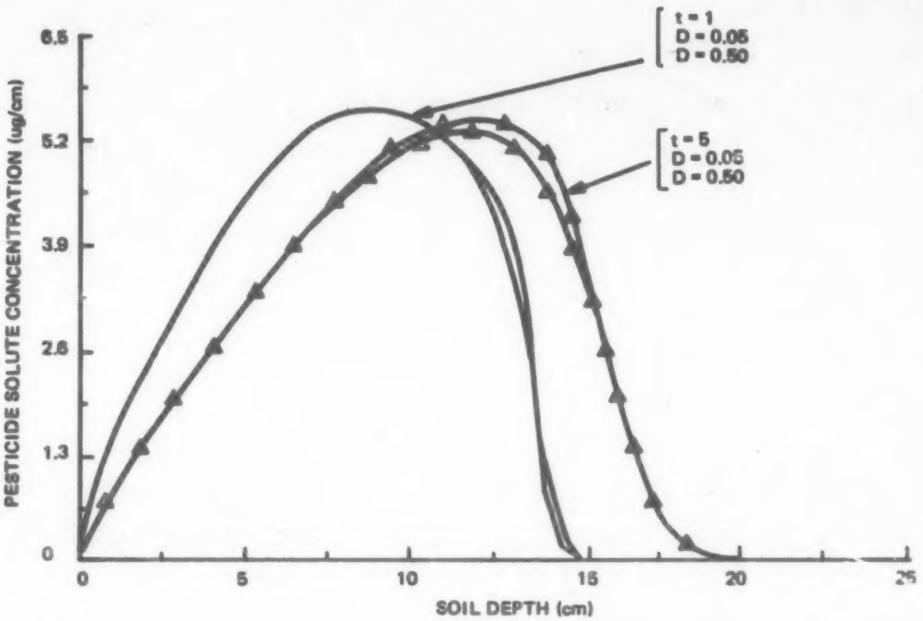


Figure 97. Diffusion coefficient vs. solution concentration distribution

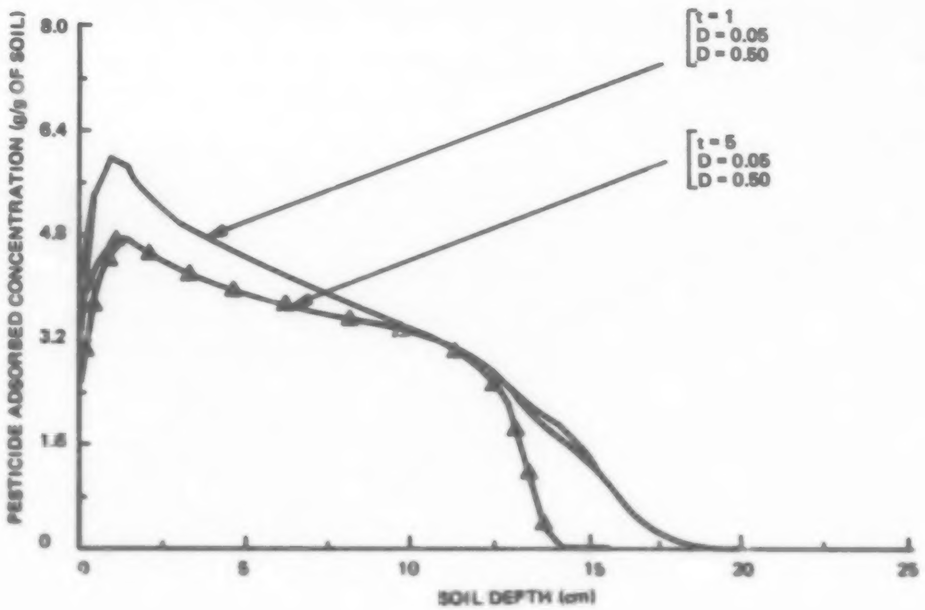


Figure 98. Diffusion coefficient vs. adsorbed concentration distribution

Moe[51] investigated the kinetics of microbial degradation of the herbicides IPC and CIPC. From an equation based on both the herbicide concentration and the bacterial mass present in the system, the reaction rate constants for the initial hydrolysis reactions were calculated. Moe determined that the greater persistence of the herbicide CIPC was more dependent upon the degree of microbial activity rather than upon an activation energy requirement.

Burschel and Freed[52] studied the rate of micro-biological decomposition of three organic herbicides in the soil. To ascertain the kinetics involved in the process, the rate was followed at two different temperatures. They reasoned from both first principles and observations that since most microbiological processes follow first order kinetics, then the decomposition of the herbicides in the soil should also follow first order kinetics. On this basis it would be possible to calculate the heat of activation required for this breakdown, by applying the Arrhenius equation. The data they presented supported this conclusion.

Schultz and Tweedy[53] investigated the uptake and metabolism of diphenamid in resistant (tomato) and susceptible (wheat) plants. They proposed a degradation scheme for diphenamid in plants, and examined the toxicity of the herbicide and its metabolism in tomato and wheat plants.

Freed[54] determined that as a first approximation, degradation of the herbicides examined followed a first order rate law.

Several mathmatical models have been proposed to describe the degradation process: first order kinetics, Michaelis-Menton kinetics, half-order kinetics, and more complex schemes.

Steen[55] (from SERL/EPA) has developed a first order model including soil moisture and temperature factors:

$$-\frac{dCp}{dt} = K_{(M,T)}Cp \tag{59}$$

The equation is solved:

$$Cp = [Cp]_o e^{-K_{(M,T)}t} \tag{60}$$

The model has been tested using a combination of laboratory and field data. The herbicide used to calibrate the model was diphenamid.

The temperature and moisture dependence of degradation is expressed:

$$K_{(M,T)} = K_{opt}e^{(AK(M_{(t)}-M_{opt})^2)}e^{(BK(T_{(t)}-T_{opt}))}$$

$$x\left[\frac{T_{max}-T_{(t)}}{T_{max}-T_{opt}}\right]^{BK(T_{max}-T_{opt})} \tag{61}$$

Parameters AK and BK are herbicide dependent. Parameter AK is determined by the relationship of soil moisture levels to the herbicide decay rate.

AK assumes soil moisture has a Gaussian distribution with time. BK is an empirical fitting parameter which includes the effects of biological components of degradation. Environmental parameters include: T, M, K_{opt}, T_{opt}, M_{opt}, and T_{max}. K_{opt} is the decay rate at the optimal temperature. T_{opt} is the optimal temperature expressed in degrees C. T_{max} is the maximum temperature and M_{opt} is the optimal moisture level.

The boundary conditions in the model involve the temperature. An increased temperature increases the rate of degradation. As the temperature approaches 40°C, the rate of biological degradation decreases. At higher temperatures (between 42° - 45°C) degradation ceases.

Experimental Degradation Data

Herbicide data was collected on the watersheds and attenuation plots. Pesticide loss was plotted against elapsed time in days of the watersheds. Both atrazine and diphenamid appear to exhibit a first-order decay (Figures 99 thru 102). Paraquat core sample data (Figures 103 thru 106) does not show a consistent decay pattern with time. Paraquat levels within a watershed will inexplicably increase over a period of time after dropping to a lower level. Paraquat data was not simulated using the herbicide degradation model because of fluctuations in the degradation of the core sample data.

Averaged data for diphenamid (Figure 107) and paraquat (Figure 108) from attenuation plots in 1972 have been plotted against time. The two pesticides show erratic fluctuations. An improved coring technique was devised to prevent contamination of subsurface soil. This technique has provided remarkably improved data for 1973.

Diphenamid core data from watershed P-01 and atrazine core data from watershed P-04 were compared to simulated results using only the degradation model (Figures 109 and 110). The environmental parameters used in this simulation were optimal moisture and a 20°C temperature.

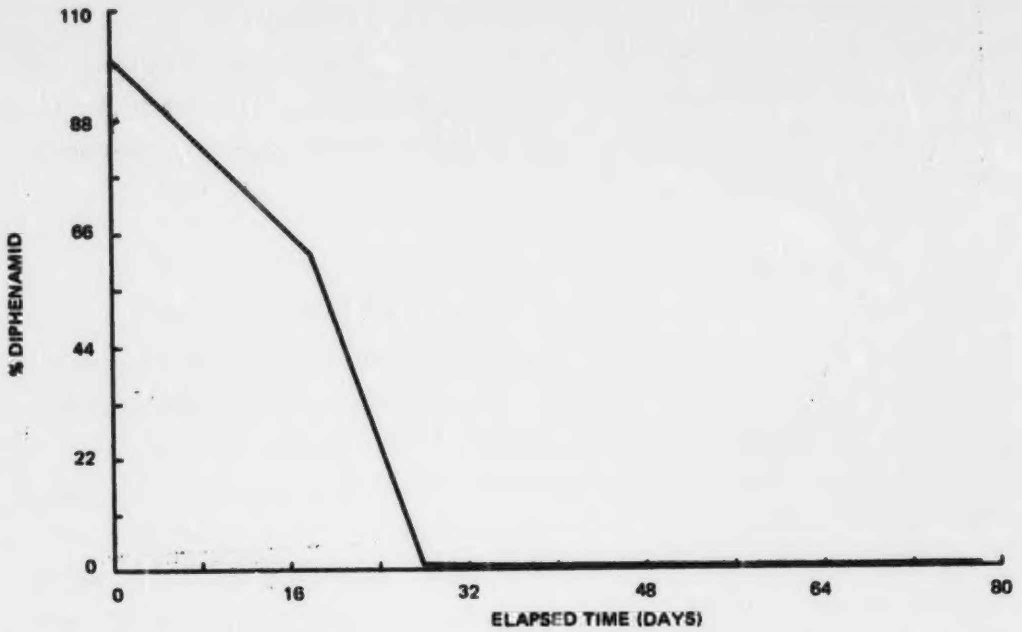


Figure 99. P-01 watershed: percent of applied diphenamid remaining during the 1973 growing season based on averaged core sample data

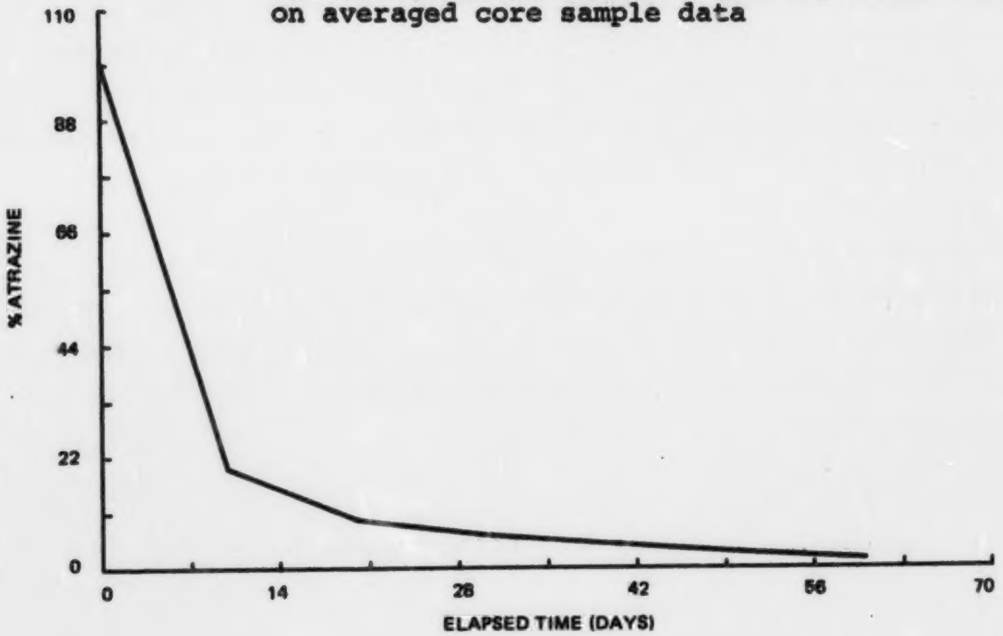
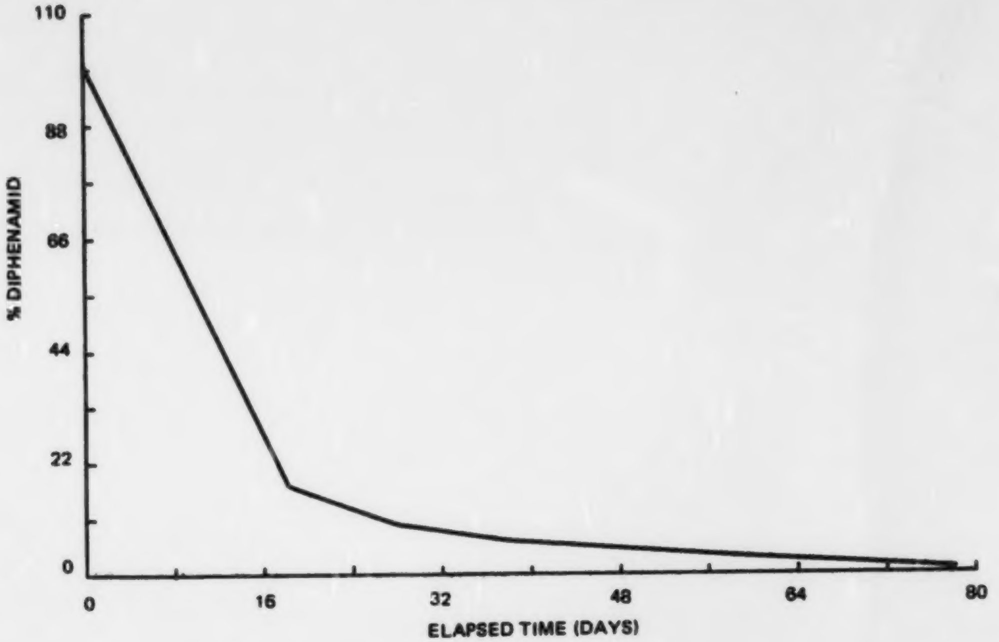


Figure 100. P-02 watershed: percent of applied atrazine remaining during the 1973 growing season based on averaged core sample data



Fiqure 101. P-03 watershed: percent of applied diphenamid remaining during the 1973 growing season based on averaged core sample data

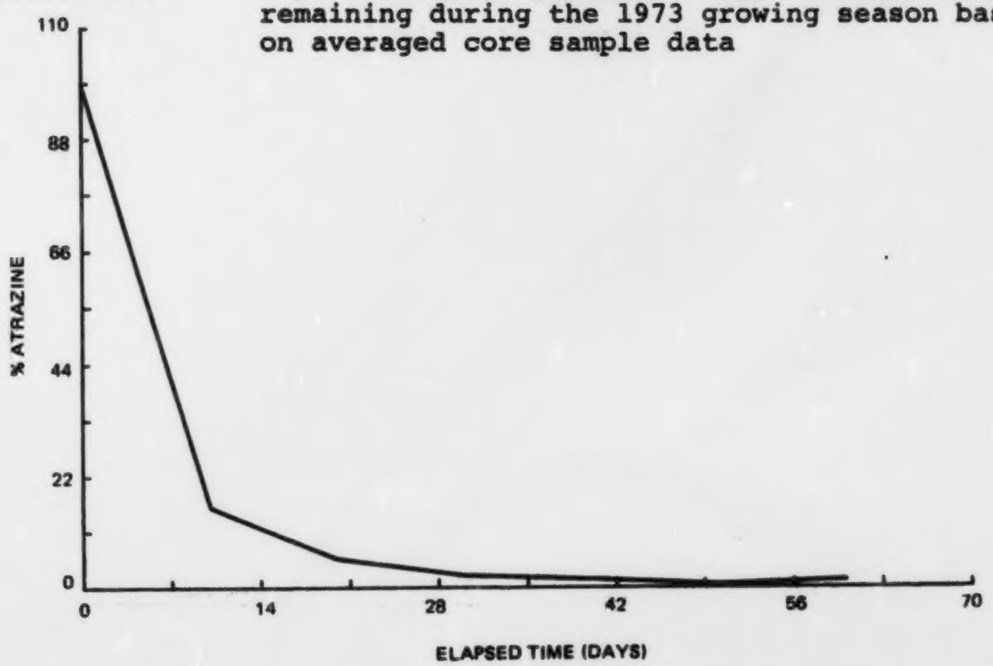


Figure 102. P-04 watershed: percent of applied atrazine remaining during the 1973 growing season based on averaged core sample data

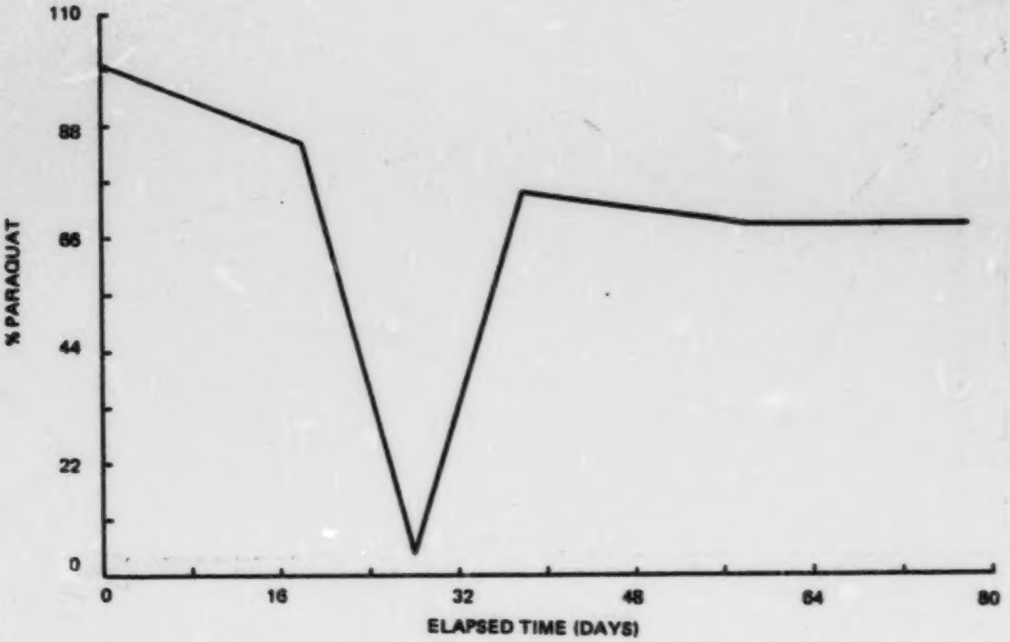


Figure 103. P-01 watershed: percent of applied paraquat remaining during the 1973 growing season based on averaged core sample data

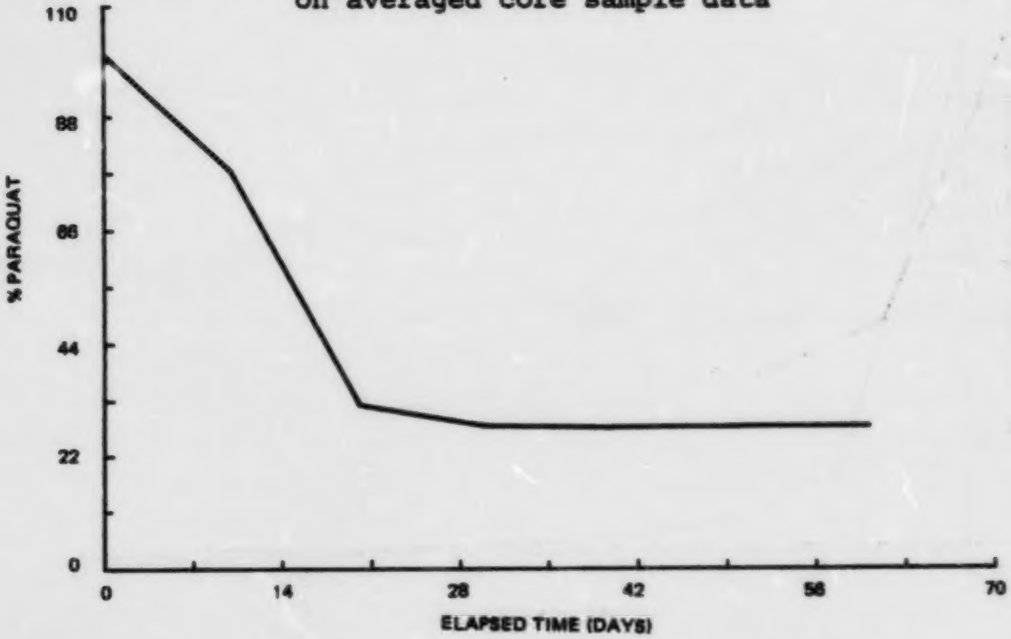


Figure 104. P-02 watershed: percent of applied paraquat remaining during the 1973 growing season based on averaged core sample data

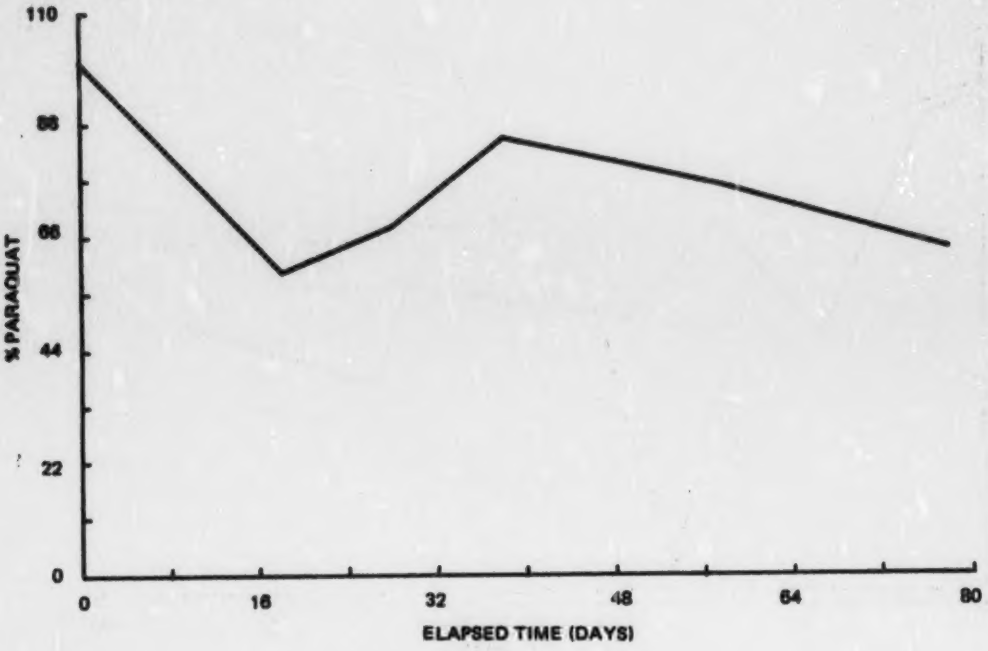


Figure 105. P-03 watershed: percent of applied paraquat remaining during the 1973 growing season based on averaged core sample data

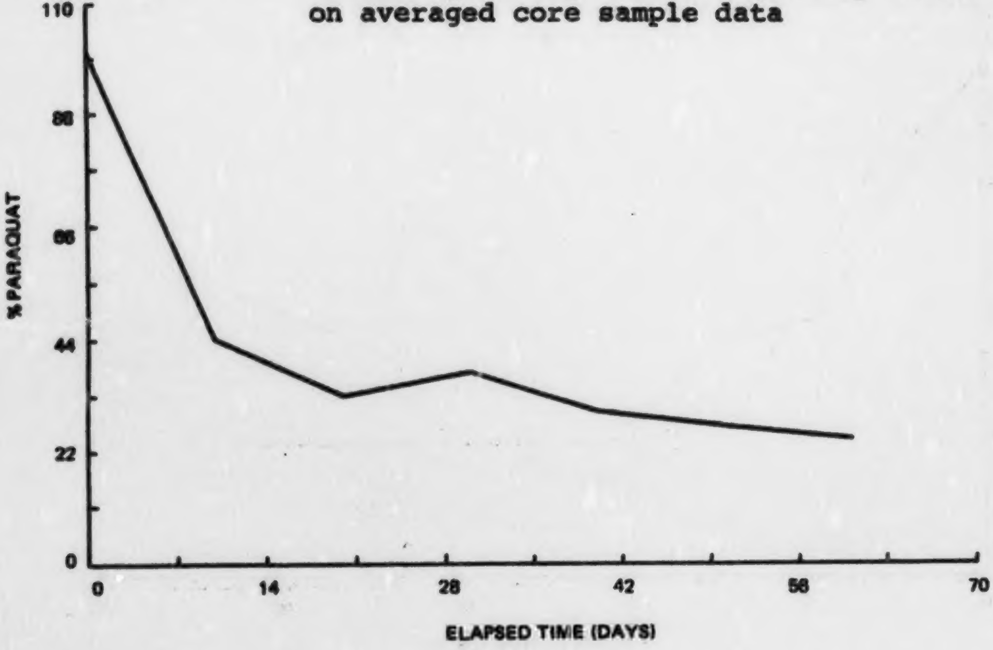


Figure 106. P-04 watershed: percent of applied paraquat remaining during the 1973 growing season based on averaged core sample data

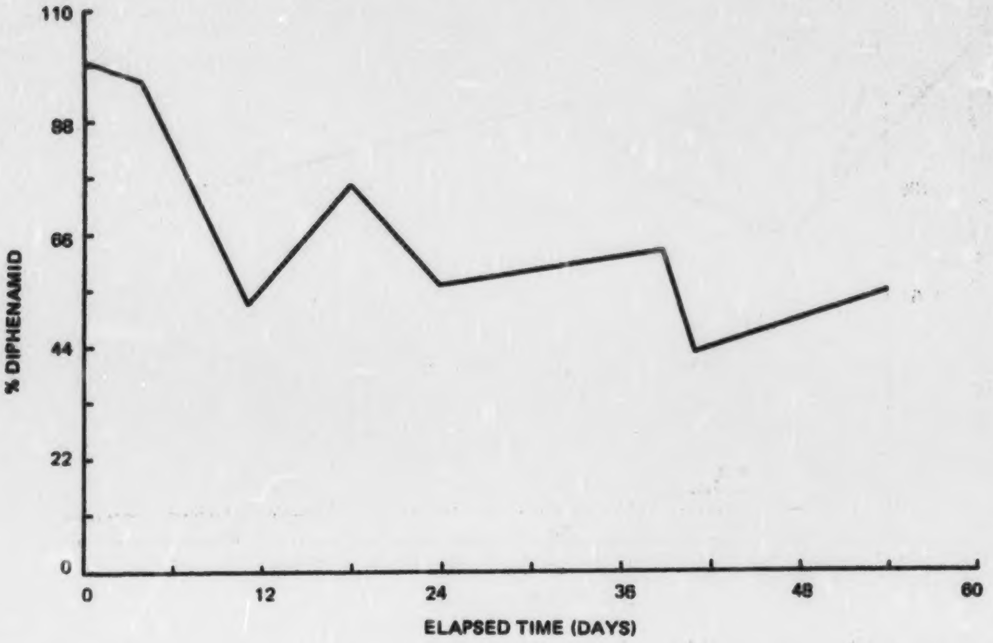


Figure 107. Percent of applied diphenamid remaining on attenuation plots during the 1972 growing season averaged over all samples

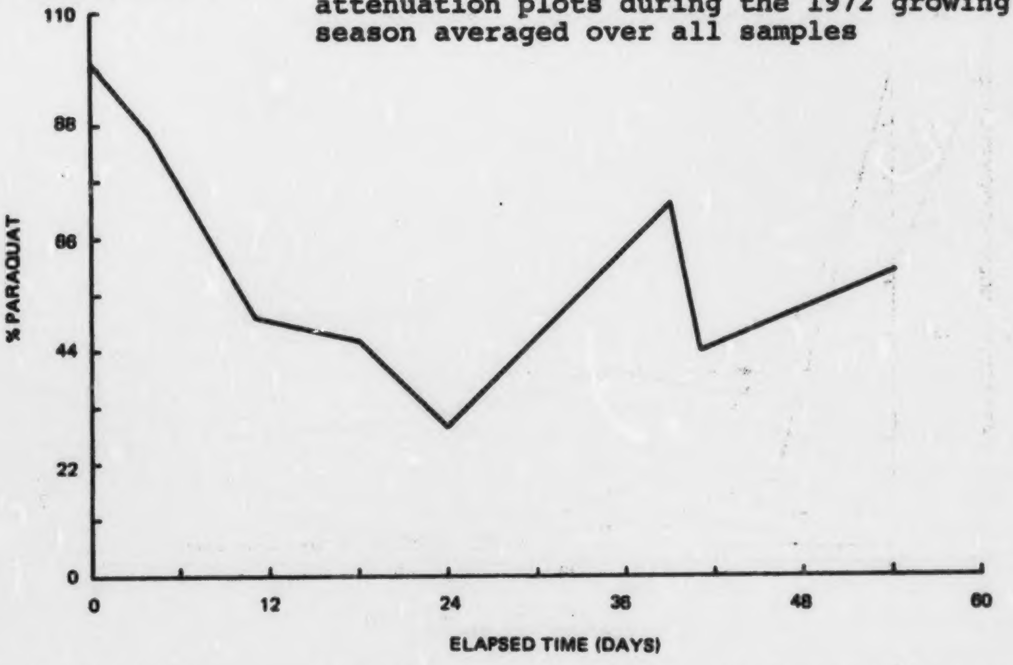


Figure 108. Percent of applied paraquat remaining on attenuation plots during the 1972 growing season averaged over all samples

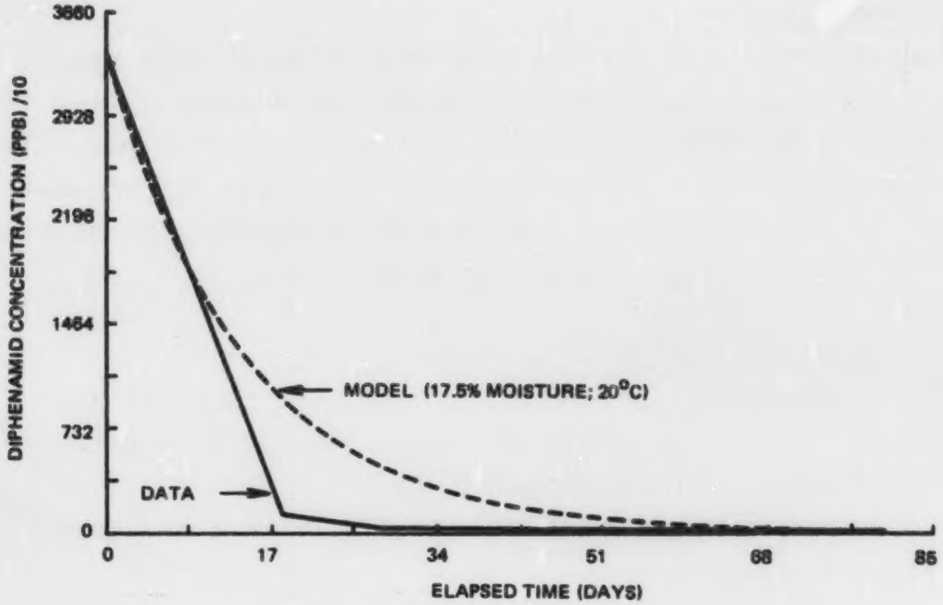


Figure 109. Watershed P01: comparison of simulated versus actual diphenamid degradation

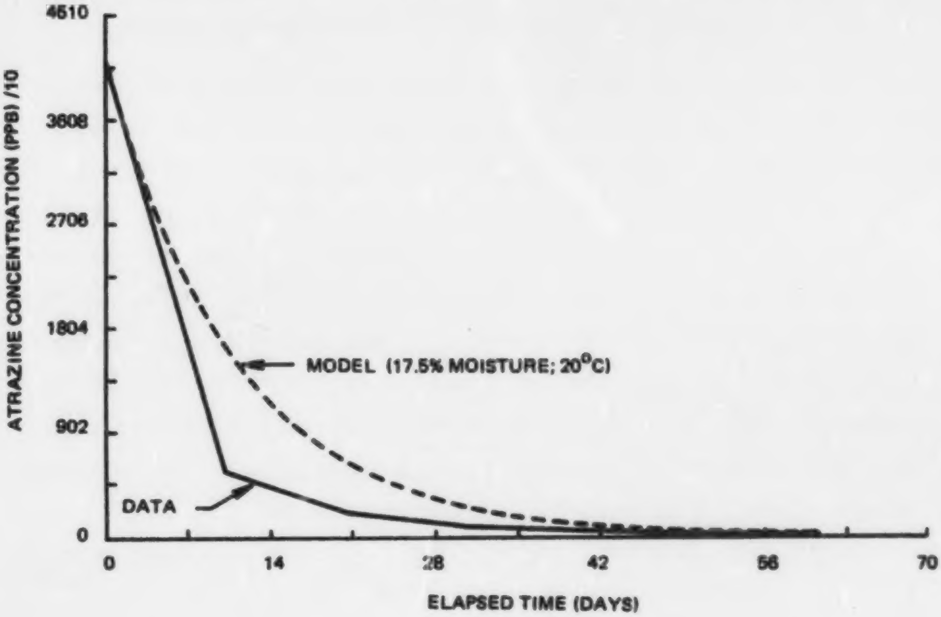


Figure 110. Watershed P04: comparison of simulated versus actual atrazine degradation

Degradation Sensitivity Tests

Sensitivity tests for the degradation model were performed for two distinct groups of model parameters: (1) environmental parameters, and (2) pesticide specific parameters. All tests were run for a period of 80 days. All the parameters examined in the sensitivity analysis are factors which determine the decay constant $K_{(M,T)}$ (Equation 61).

Sensitivity to environmental parameters -

The environmental parameters tested were moisture and temperature. For these tests the pesticide specific parameters AK, BK were assigned diphenamid values.

The parameters used to calculate K(M,T) were assigned the following values:

$K_{opt} = .119676$ $T_{max} = 39.6065$
$M_{opt} = .173599$ $AK = 92.0040$
$T_{opt} = 38.2344$ $BK = 0327710$

Moisture was found to be the more sensitive environmental parameter. Moisture sensitivity of the degradation model was tested over the range of 0% to 35% moisture. Figures 111 through 115 illustrate the effects on degradation of 0% of moisture, 35% moisture, and 17.5% moisture. These three moisture levels were plotted for five temperatures: 0°C, 10°C, 20°C, 30°C, and 35°C. Both maximal and minimal moisture produce minimal degradation at all temperatures examined. A moisture level of 17.5% produces near optimal degradation at all temperatures examined. The effect of moisture on degradation was graphed over a range from 5 percent to 30 percent moisture in 5 percent increments (Figure 116). The extremes of this range, 5

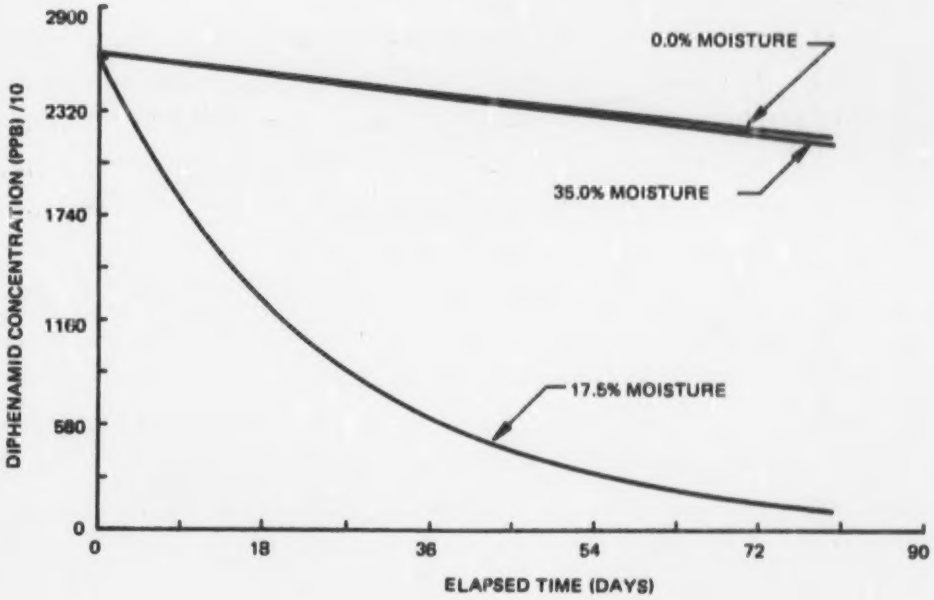


Figure 111. Sensitivity of the degradation model to moisture at 0°C

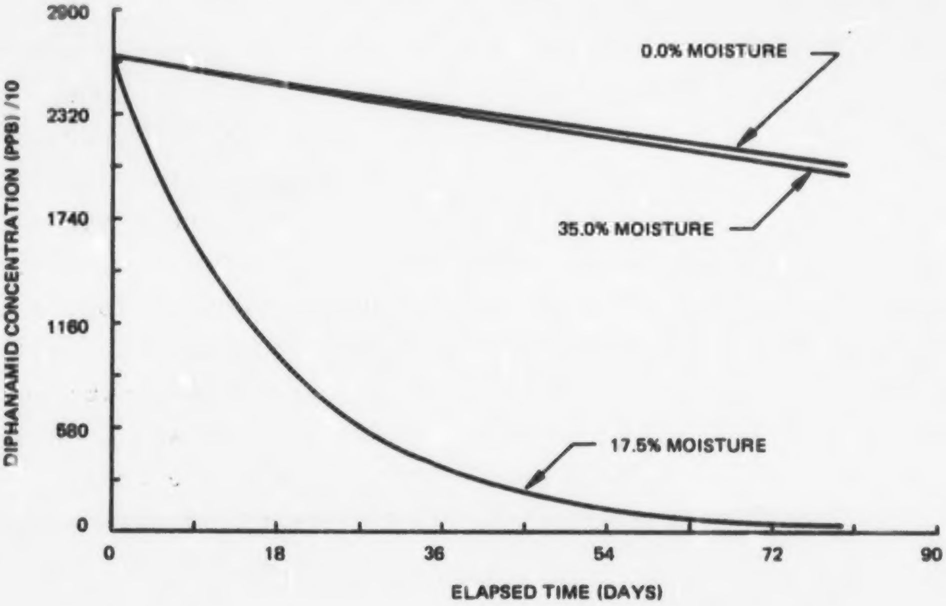


Figure 112. Sensitivity of the degradation model to moisture at 10°C

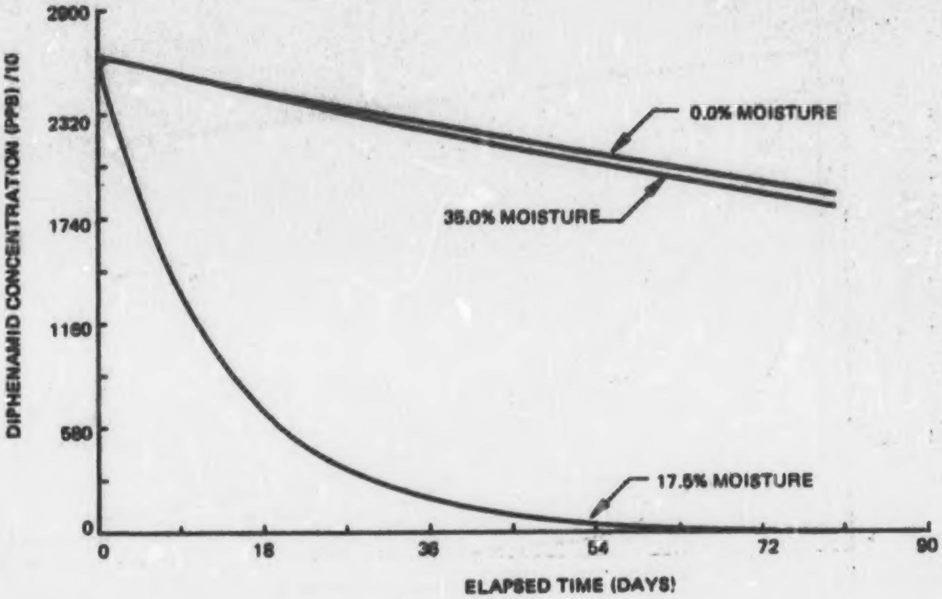


Figure 113. Sensitivity of the degradation model to moisture at 20°C

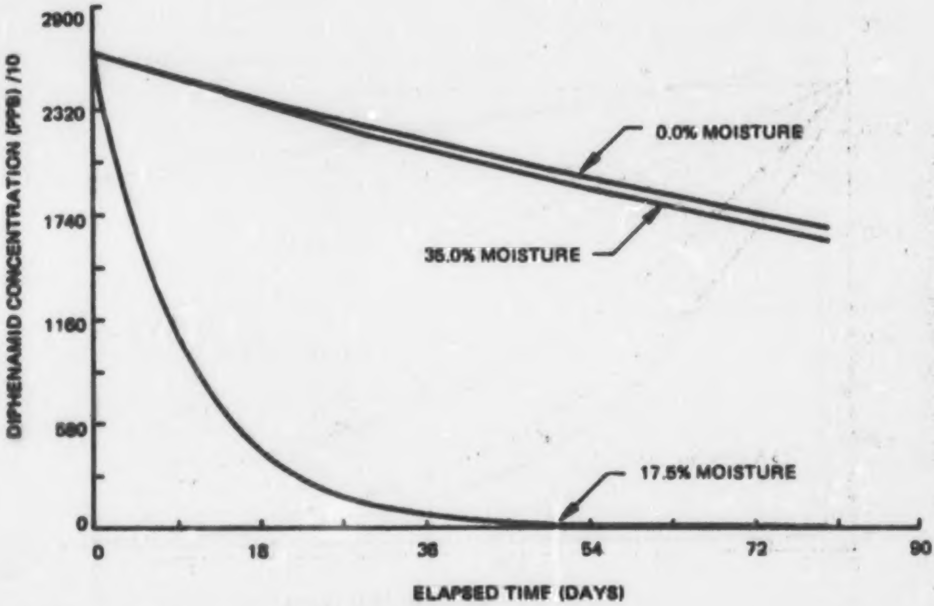


Figure 114. Sensitivity of the degradation model to moisture at 30°C

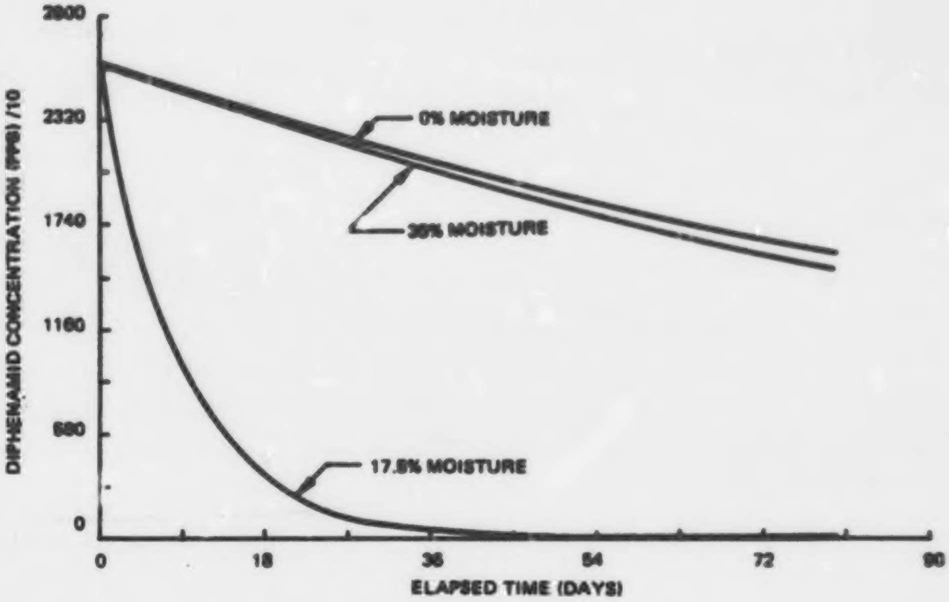


Figure 115. Sensitivity of the degradation model to moisture at 30°C

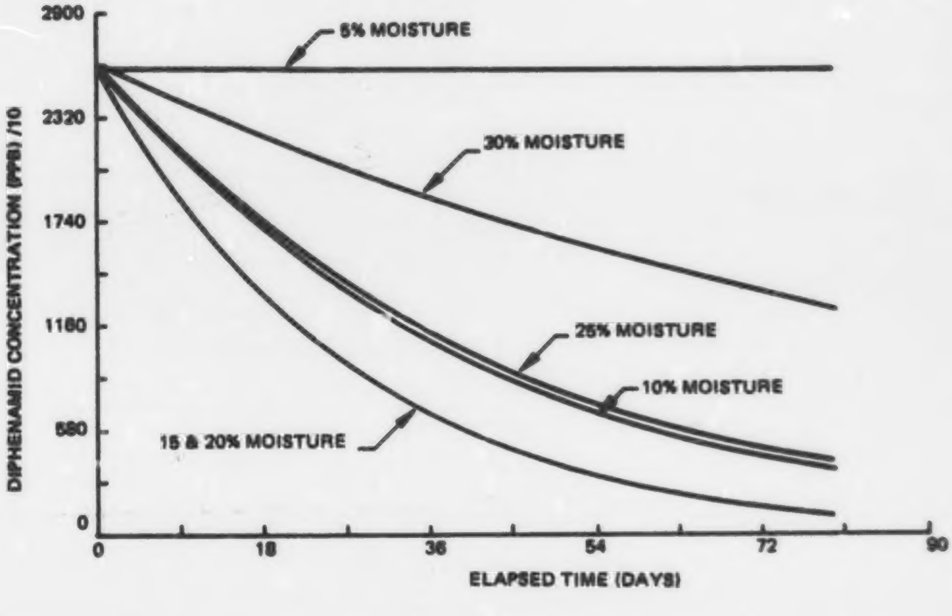


Figure 116. Sensitivity of the degradation model to moisture at 20°C

percent and 30 percent, produce relatively low degradation. Moisture levels of 10 and 25 percent produce moderate levels of pesticide degradation, while moisture levels of 15 and 20 percent product rapid degradation.

Temperature variations, while not producing the dramatic affect of moisture variation, produce significant effects. Temperature sensitivity was tested over a range from 0-35 degrees. Degradation produced at the temperatures examined (0°, 10°, 20°, 30°, and 35°) were plotted at minimal, optimal and maximal moisture levels (Figures 117 thru 119). Degradation of pesticide increases with temperatures up to 38°C. At 40°C, the degradation rate is analagous to the degradation produced at 15°C. Biological degradation ceases at temperatures between 40°C and 45°C. The computer model currently uses 42°C pending the completion of Dr. Steen's tests.

Sensitivity to Pesticide Specific Parameters

The environmental parameters were assigned the following values for all pesticide specific sensitivity tests:

$K_{opt} = 119676$ $\quad$ $T_{max} = 39.6065$
$M_{opt} = .173599$ $\quad$ $T = 20.000$
$T_{opt} = 38.2344$ $\quad$ $M = .175000$ for tests of BK
$\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad$ $= .05000$ for tests of AK

AK characterizes the moisture dependence of pesticide degradation. The value of AK is always negative; a value of zero would produce optimal degradation at all moisture levels. The effect of increasing the absolute value of AK is the reduction of the degradation rate. AK was varied from 75 to -110 with little effect on the degradation rate (Figure 120).

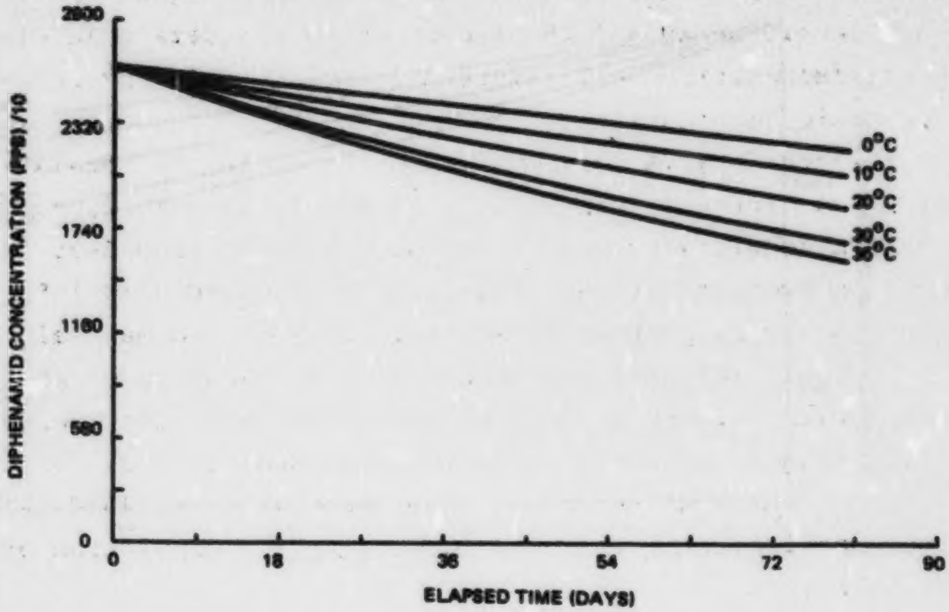


Figure 117. Sensitivity of the degradation model to temperature at minimal moisture (0%)

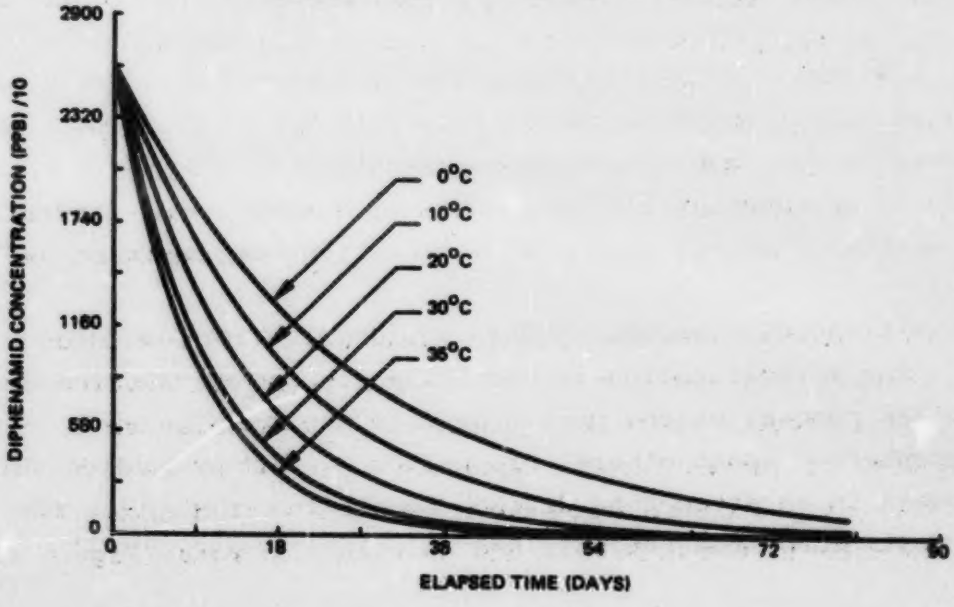


Figure 118. Sensitivity of the degradation model to temperature at optimal moisture (17.5%)

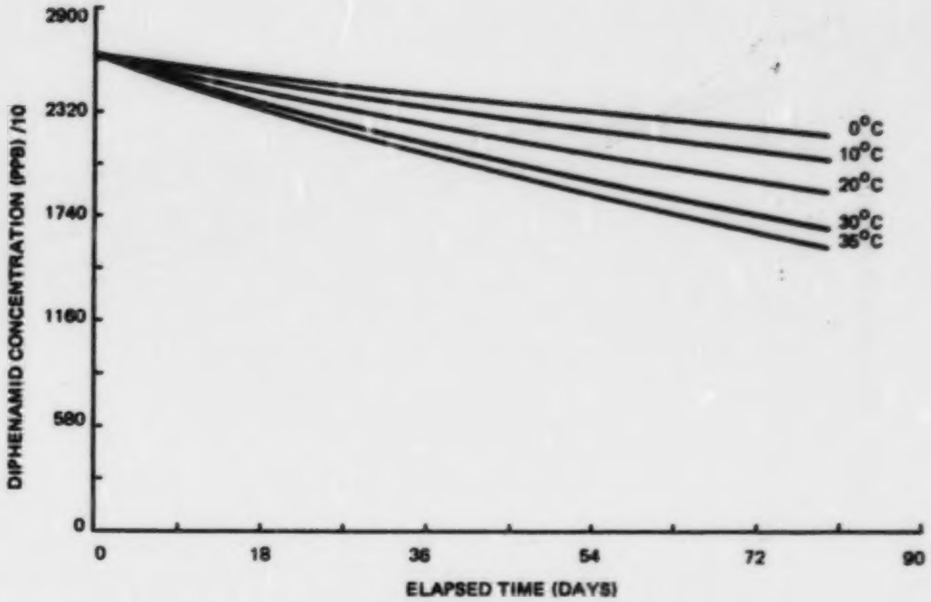


Figure 119. Sensitivity of the degradation model to temperature at maximum moisture (35%)

BK characterizes the temperature dependence of pesticide degradation. As BK increases from 0.01 to 0.05 the rate of pesticide degradation decreases (Figure 121). At BK = 0, the rate of degradation is independent of temperature. Values of BK greater than 0.5 result in little or no degradation.

VOLATILIZATION SUBMODELS (VOLT) AND SENSITIVITY ANALYSES

The volatilization of pesticides is one of the mechanisms for the removal of the pesticide from the soil to the atmosphere. Among others, Dr. Walter J. Farmer studied this process in an attempt to develop models for predicting the loss of pesticides from the soil due to volatilization.[55-60]

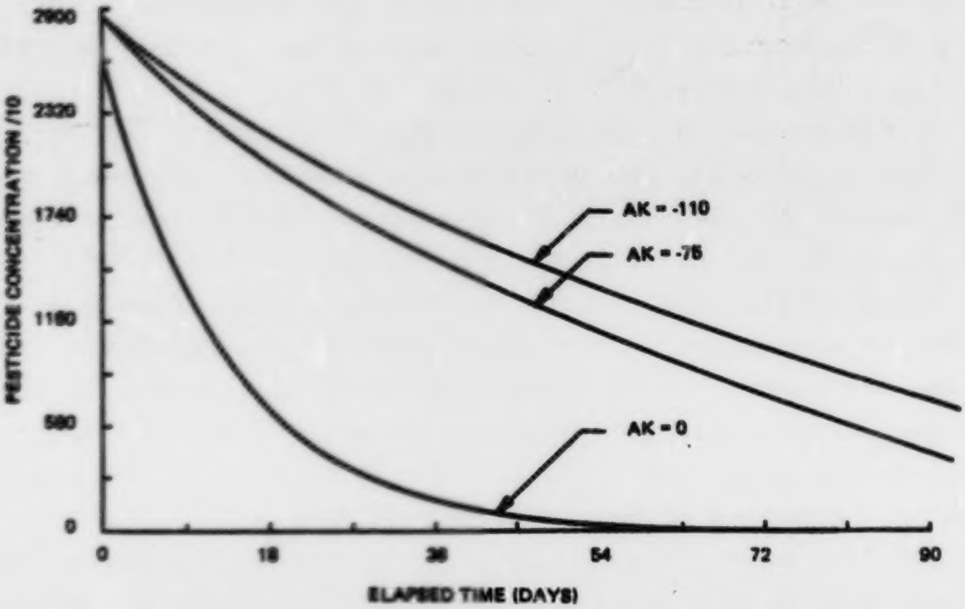


Figure 120. Sensitivity of the degradation model to the pesticide specific parameter-AK

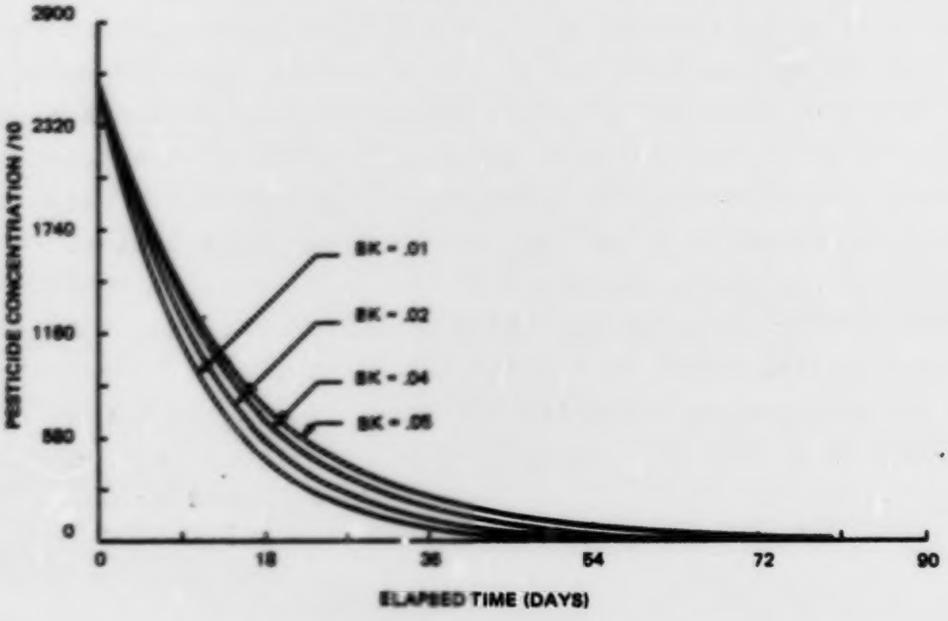


Figure 121. Sensitivity of the degradation model to the pesticide specific parameter-BK

His recent paper contained five models describing the volatilization of pesticides with varying initial and boundary conditions and transport processes.[61]

Farmer notes that the volatilization of pesticides can be predicted by studying the physical and chemical processes which control the pesticide concentrations at the soil surface. When pesticide concentration at the surface is high, volatilization is primarily governed by the pesticide vapor pressure and degrees of adsorption in the soil. When concentrations at the surface are lower, however, volatilization is governed by the movement of the pesticides through the soil to the surface. The pesticide transport can be by either one or both of the possible transport processes of mass flow and diffusion.

The five Farmer models are more accurately designated as distinct solutions to a single equation. The basic assumption is that the movement of the pesticide in soils under concentration gradient can be mathematically treated using the standard equation. The change in concentration of the pesticide, as well as the loss of pesticides due to volatilization at the surface, is predicted by the solution of the diffusion equation using five different sets of boundary conditions. Because of the similarity of (1) the diffusion equation and the transfer of matter into a concentration gradient described by Fick's second law and (2) the heat transfer equation described by Fourier's law, it is possible to use known solutions of the heat transfer equation to describe pesticide movement. If the soil is assumed to be an isotropic system, wherein a pesticide is uniformly mixed with a layer of soil and is volatilized at the soil surface, the diffusion equation is:

$$\frac{\partial^2 C}{\partial z^2} - \frac{1}{D}\frac{\partial C}{\partial t} = 0\text{: Fick's Second Law} \qquad (62)$$

where: C = the pesticide concentrated in the soil (g/cm^3 total volume)

z = distance measured normal to the soil surface (cm)

D = diffusion coefficient (cm^2/sec)

t = time (sec).

The solution of this equation with the five sets of boundary conditions has been described by Farmer.[61] The actual closed form solutions are obtained through comparison to similar heat transfer situations described in H.S. Carslaw and J.C. Jaeger.[62] Portions of Farmer's paper are duplicated and discussed below for the convenience of the user.

Model I

The first model assumes that the pesticide volatilizes at the soil surface. Pesticide is initially incorporated uniformly to a depth L at concentration C_o (g/cm^3). No pesticide diffuses below L. Mathematically these conditions are:

$$C = C_o \text{ at } t = 0;\ 0 \le Z \le L$$
$$C = 0 \text{ at } Z = 0 \text{ and } t > 0$$
$$\frac{\partial C}{\partial Z} = 0 \text{ at } Z = L$$

The solution to (62) by analogy to the heat equation is: (63)

$$C = \frac{4C_o}{\pi} \sum_{n=o}^{\infty} \frac{(-1)^n}{(2n+1)} \left\{ e^{(-D(2n + 1)^2 \pi^2 t/4L^2)} \right.$$

$$\left. \times \cos \frac{(2n + 1) \pi (L-Z)}{2L} \right\} \qquad (64)$$

Pesticide flux, $f = D \left(\frac{\partial C}{\partial z}\right)_{z = 0}$ is given by

$$f = \frac{D\ C_o}{(\pi Dt)^{1/2}} \left[1 + 2 \sum_{n=1}^{\infty} (-1)^n e^{(-n^2 L^2/Dt)} \right] \qquad (65)$$

Model II

If the summation term in (65) is small compared to one, the flux reduces to:

$$f = \frac{D\ C_o}{(\pi Dt)^{1/2}} \qquad (66)$$

By analogy to heat flow in an infinite solid, the concentration is given by:

$$C = C_o \operatorname{erf} \left[z/2(Dt)^{1/2} \right] \qquad (67)$$

A test for the validity of (66) suggested by Farmer is $C(z = L, t) \geq 0.99C_o$. For this to be true it is easy to show that:

$$t < L^2/14.4\ D$$

For L = 1 cm and D = 8.64 x 10^{-3} cm^2/day, Equation (66) is valid for 8 days. Bode[20] et al reported diffusion coefficients for trifluralin between 10^{-8} and 10^{-6} cm^2/sec. Under conditions which are likely to occur in the field, values larger than 10^{-7} cm^2/sec (8.64 x 10^{-3} cm^2/day) are unlikely. Accordingly, Equation (66) would be valid for 8 days for L = 1 cm and for 200 days L = 5 cm.

Advanced Models

The remaining models discussed by Farmer attempt to account for the weakness of the assumed boundary conditions (Equation 63).

Farmer's Model III addresses the fact that diffusion can occur across the lower boundary, i.e.,:

$$\frac{\partial C}{\partial z} \neq 0 \text{ at } Z = L \qquad (68)$$

For reasons which will be discussed in detail below, this is not a significant error because of a more fundamental problem.

The remaining two models discussed by Farmer deal with the assumption that the pesticide concentration at the soil surface is zero at t > 0. Both models have the effect of reducing the pesticide flux at the surface.

Fundamental to all of the Farmer models is the assumption that the pesticide is uniformly incorporated to a depth L. As can be seen from Figure 122 (smoothed data) the pesticide is far from uniformly incorporated. Hence the derivation of the equations which are the basis for all of Farmer's models is highly questionable. Accordingly, at this time we have only coded the simpler models hereinafter referred to as Model I and Model II.

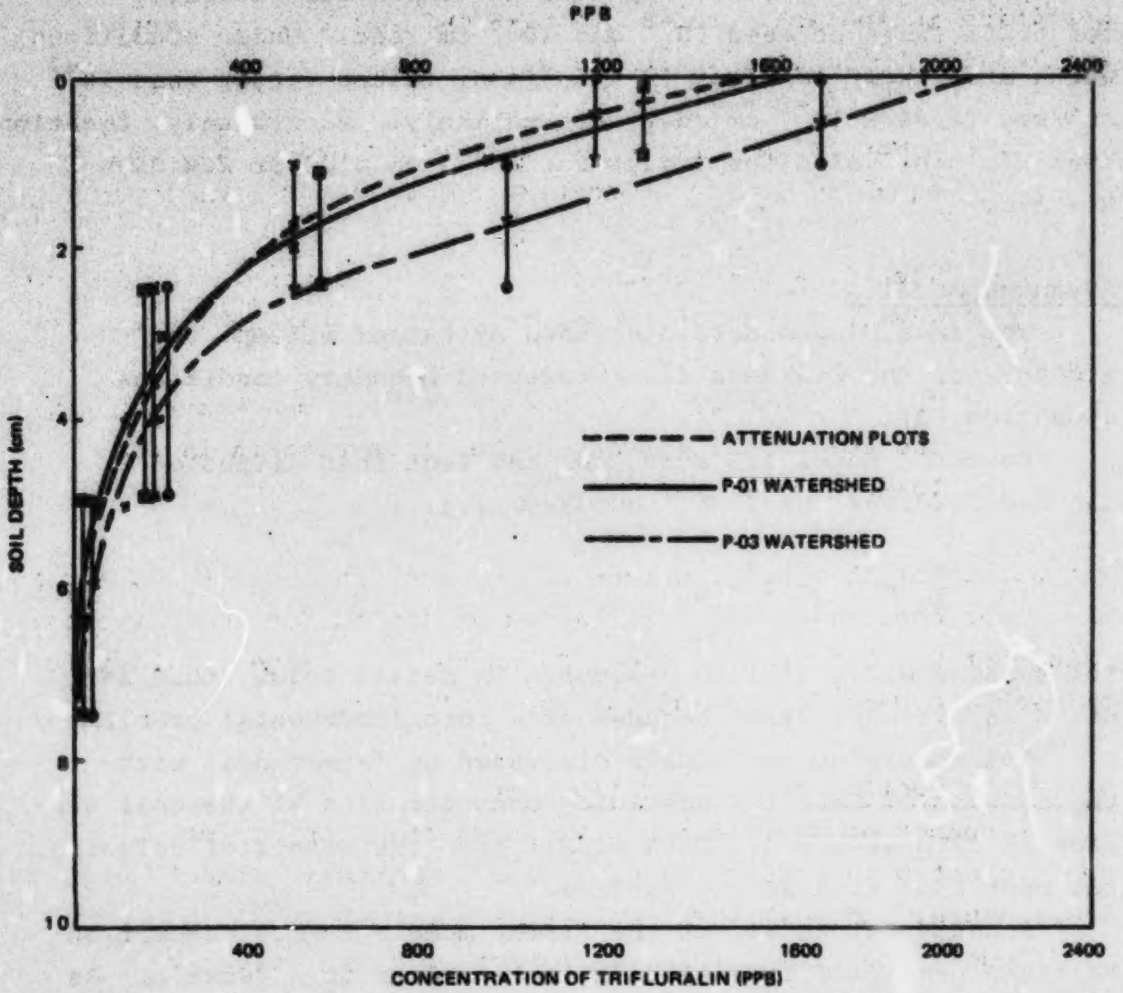


Figure 122. Measured Trifluralin distribution in the soil profile after application, 1973

Adjustment for Non-Uniform Pesticide Application

In order to adjust for the lack of uniformity of pesticide in the soil profile, Equations (65) and (66) were applied in the following manner:

1. L was defined to be one centimeter and C_o was set equal to C_1, the concentration in the 0-1 cm layer.

2. When C_1 was reduced to the concentration in the 1-2 cm layer, C_o was set equal to C_2 and L was set to 2.0 cm.

3. This process was continued until the concentration in the soil profile reached the concentration in the lowest centimeter.

The effect of this modification can be seen in Figures 123 and 124. For comparison Model II has been plotted for two different values of C_o: 5000 ng/cm^3 and 1400 ng/cm^3. A value of 1.0×10^{-7} cm^2/sec was used for the diffusion coefficient.

Diffusion Coefficient for Trifluralin

A number of experiments have shown that the diffusion coefficient D is a function of the soil moisture content, soil temperature, and soil bulk density.

Bode[20] used a multiple regression analysis to derive a 15 term equation for predicting the diffusion coefficient from trifluralin:

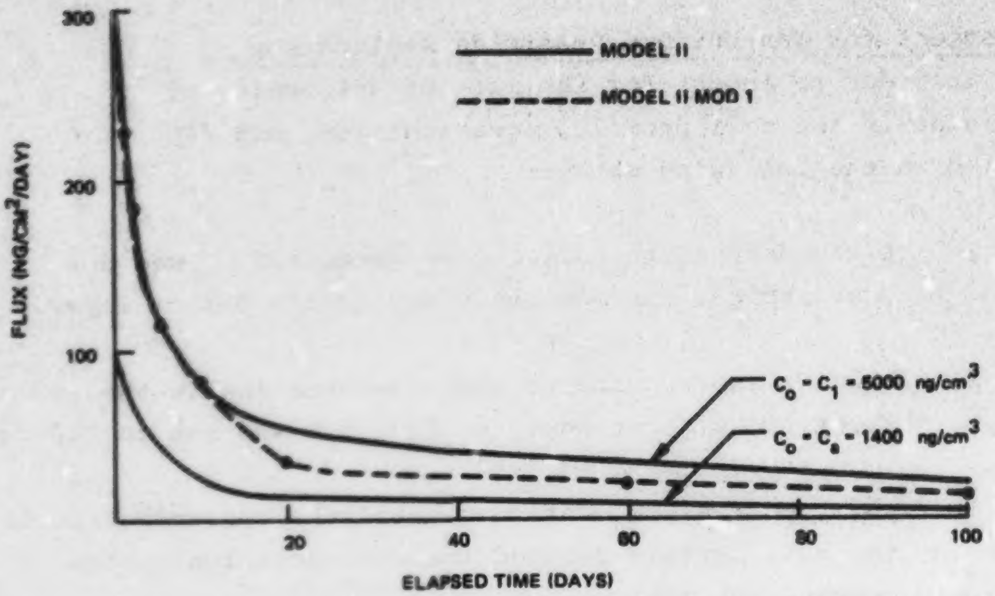


Figure 123. Calculated pesticide flux for different initial conditions

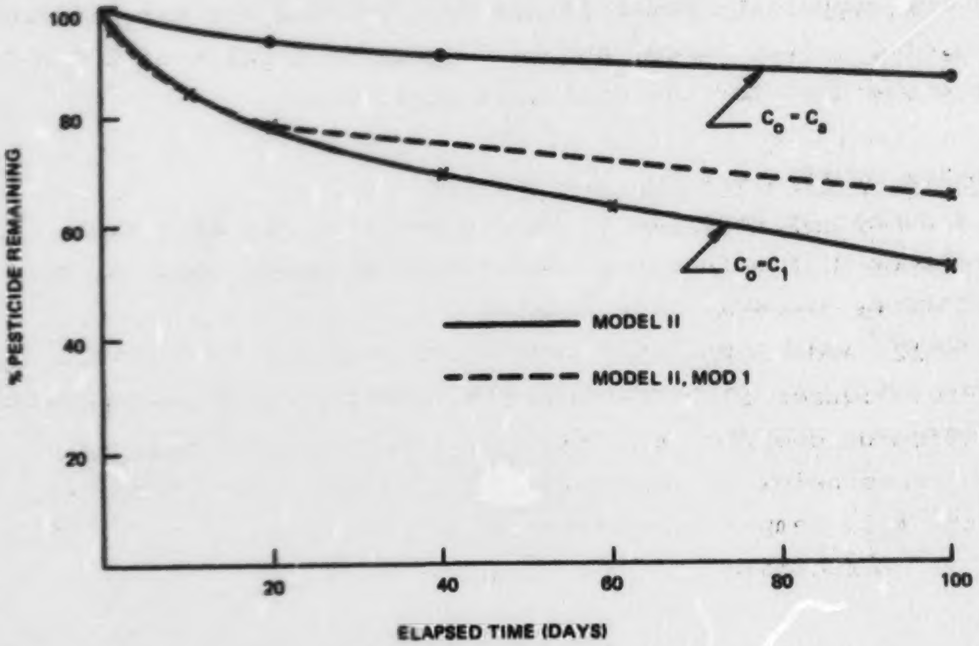


Figure 124. Pesticide remaining for different initial conditions

$$\begin{aligned}\log D = {} & - 0.313 - 1.051\,\theta + 0.054(\theta)^2 \\ & - 8.494 \times 10^{-4}\theta^3 - 8.997\,\rho \\ & + 6.021 \times 10^{-5}\theta T^2 - 7.359 \times 10^{-7}\theta T^3 \\ & + 1.483 \times 10^{-6}\theta^4 T - 8.863 \times 10^{-8}\theta^5 T \\ & + 1.362 \times 10^{-9}\theta^6 T + 1.588\theta\rho \\ & - 0.108\theta^2\rho + 2.880 \times 10^{-3}\theta^3\rho \\ & - 2.560 \times 10^{-5}\theta^4\rho + 4.664 \times 10^{-2}T\rho \\ & - 3.013 \times 10^{-3}\theta T\rho \end{aligned} \tag{69}$$

where θ = soil moisture (% w/w)
T = soil temperature (°C)
ρ = bulk density (g/cm^3)

The multiple correlation coefficient (R) for Equation (69) was 0.99, which is very satisfactory.

Equation (69) was derived from experimental results for Mexico Silt Loam of varying bulk densities. The soil was reported to be 2.5% organic matter, 75% silt, and 22% clay and had a pH of 5.6.[20]

Equation (69) predicts that D will decrease with increasing bulk density for constant temperature and moisture. For constant moisture and bulk density, D increases as temperature increases. For constant bulk density and temperature, D increases and then decreases as moisture content is varied between 0 and 30%(see Figures 125 and 126).

From Figures 125 and 126 and Equation (69) we can see that the diffusion coefficient drops off rapidly as the moisture content goes below 5% regardless of the soil temperature, and when the soil temperature drops below 25°C there is very little change in D regardless of the moisture content.

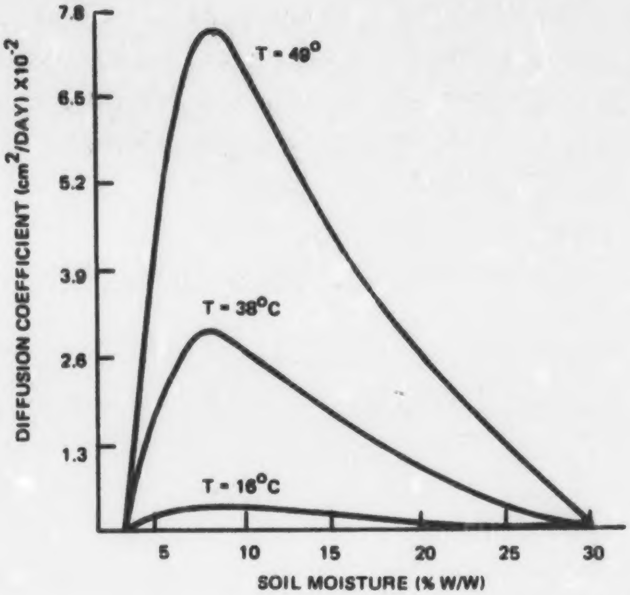


Figure 125. Calculated trifluralin diffusion coefficient for Mexico Silt Loam (Bulk density 1.4 g/cc)

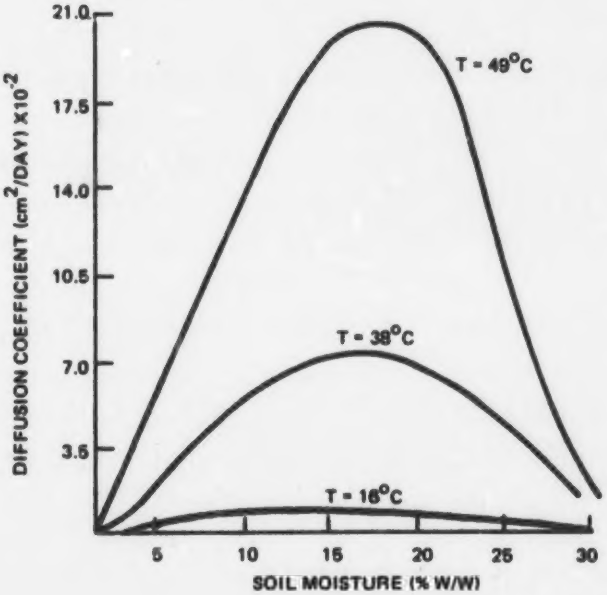


Figure 126. Calculated trifluralin diffusion coefficient for Mexico Silt Loam (Bulk density 1.0 g/cc)

Assuming that high soil temperatures will not be associated with high moisture content, a range of values for D can be estimated for field conditions. For Mexico Silt Loam of bulk density 1.4 g/cm^3, this range would be approximately 9×10^3 cm^2/day (moist, 25°C) to 5×10^2 cm^2/day (dry, 45°C).

Model Sensitivity to the Diffusion Coefficient and Soil Profile Distribution

In order to test the model sensitivity to the diffusion coefficient D, an initial distribution of pesticide in the soil profile must be assumed. Unless otherwise noted, the application amount is assumed to be 11,220 ng/cm^2, distributed in the first eight centimeters as follows:

45%, 28%, 14%, 6%, 3%, 2%, 1%, 1%.

The flux predicted by Model II increases as the square root of the diffusion coefficient. As D increases the non-uniform incorporation of pesticide becomes more significant. For large values of D the flux at the surface due to the high concentration of pesticide in the 0-1 centimeter layer will be very large. As a result the concentration in the 0-1 cm layer is reduced very rapidly to the concentration in the 1-2 layer (less than two days for the conditions outlined above). These results suggest that between 5 and 10% of the total amount applied could be lost in the first 4-8 hours after application. The sensitivity to D is shown in Figure 127.

Because of the possible sensitivity to the initial profile of pesticide in the soil, a series of computer runs were made with D held constant at 8.64×10^{-2} cm^2/day, and the total application fixed at 11,220 ng/cm^2. If we represent the profile concentrations as percent of amount applied, in vector notation three profiles were checked: A: (73.5, 13, 6, 3, 1.5, 1,1,1), B: (45, 28, 14, 6, 3, 2, 1, 1), and C: (12.5, 12.5, 12.5, 12.5, 12.5, 12.5, 12.5, 12.5).

The results are shown in Figure 128. Table 14 summarizes the results for several values of the diffusion coefficient. The effect of initial pesticide distribution is very pronounced. For reasonable values of the diffusion coefficient significant amounts of pesticide would be lost in the first few days after application.

Table 14. PERCENT PESTICIDE REMAINING AFTER 100 DAYS AS A FUNCTION OF INITIAL DISTRIBUTION AND DIFFUSION COEFFICIENT

	Percent Remaining After 100 Days Diffusion Coefficient ($cm^2 day$)		
Pesticide Distribution	8.64×10^{-3}	8.64×10^{-2}	8.64×10^{-1}
A	36.4	15.9	2.49
B	64.0	29.2	6.0
C	86.9	58.5	0

Diffusion in the Soil Profile

None of the models discussed above predict any downward (away from the surface) diffusion of pesticide. This result would be expected for uniform incorporation but not for the non-uniform case. To correct for this effect another modification was added to Model II (Mod 2).

We assumed that the pesticide would move according to the concentration gradient, i.e., Fick's first law:

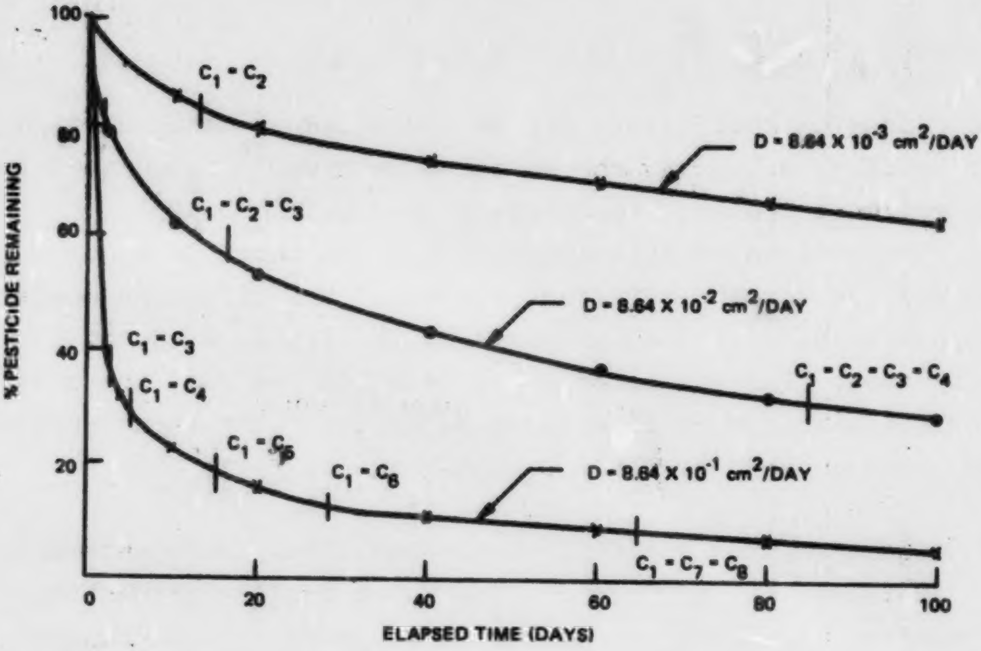


Figure 127. Sensitivity of Model II (Mod 1) to the diffusion coefficient (D)

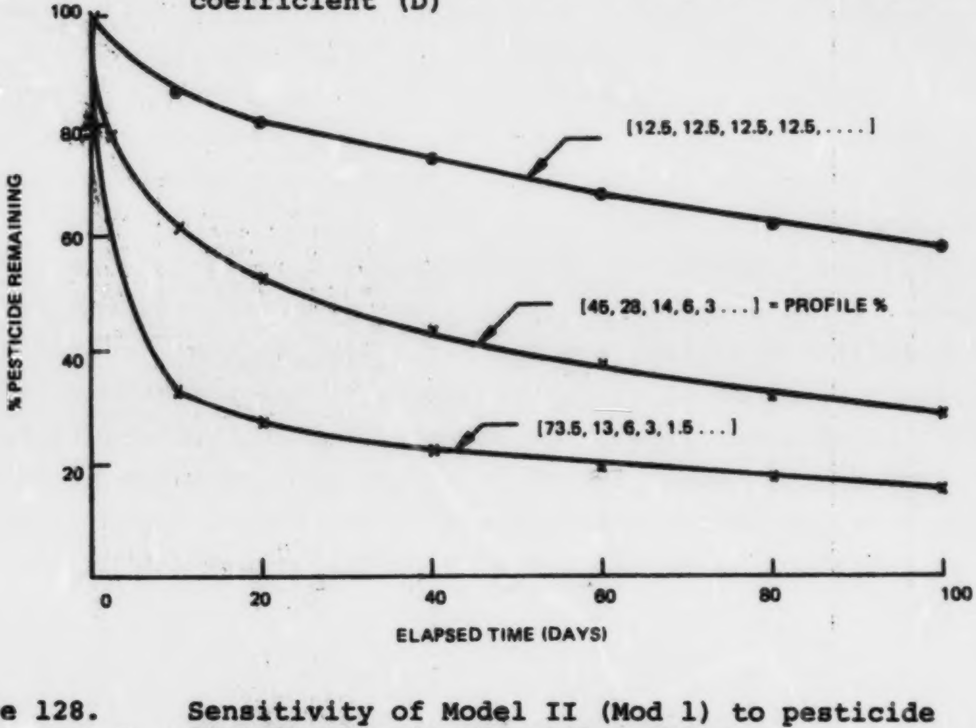


Figure 128. Sensitivity of Model II (Mod 1) to pesticide distribution in the soil profile ($D = 8.64 \times 10^{-2}$ cm^{-2}/day)

$$q = -D \frac{\partial C}{\partial z} \qquad (70)$$

The diffusion coefficient may be specified as constant throughout the profile, or, using the equation by Bode,[20] calculated from the moisture content, temperature, and bulk density.

The effects of this modification are shown in Figures 129 and 130 for two different values of the diffusion coefficient. The pesticide distribution was (60, 20, 10, 4, 2, 2, 1, 1,) for both cases. For values of $D \geq 8.64 \times 10^{-2}$ cm^2/day the model predicts significant interlayer diffusion. The total pesticide loss is also changed but not significantly.

EVAPOTRANSPIRATION SUBMODEL (EVAP) AND SENSITIVITY ANALYSES

Moisture transfer from a vegetated surface through the mechanism of evaporation is termed evapotranspiration. The word combines the two similar but distinct processes of evaporation and transpiration. Evaporation is the process whereby liquid water passes directly into the vapor state, while transpiration is the process whereby water passes from liquid to vapor via plant metabolism. The two processes are usually combined due to the fact that they are indistinguishable from one another in experimental measurements.

The net transfer of water molecules into the air as evaporation is a function of the vapor pressure gradient between the evaporating surface and the air. The gradient implies that the vapor pressure of the air adjacent to the surface is less than that at saturation. The change of state from liquid to vapor requires energy, about 582 calories per gram of water at 25°C, which necessitates an external source of energy. This could be solar radiation or sensible heat from the atmosphere on the

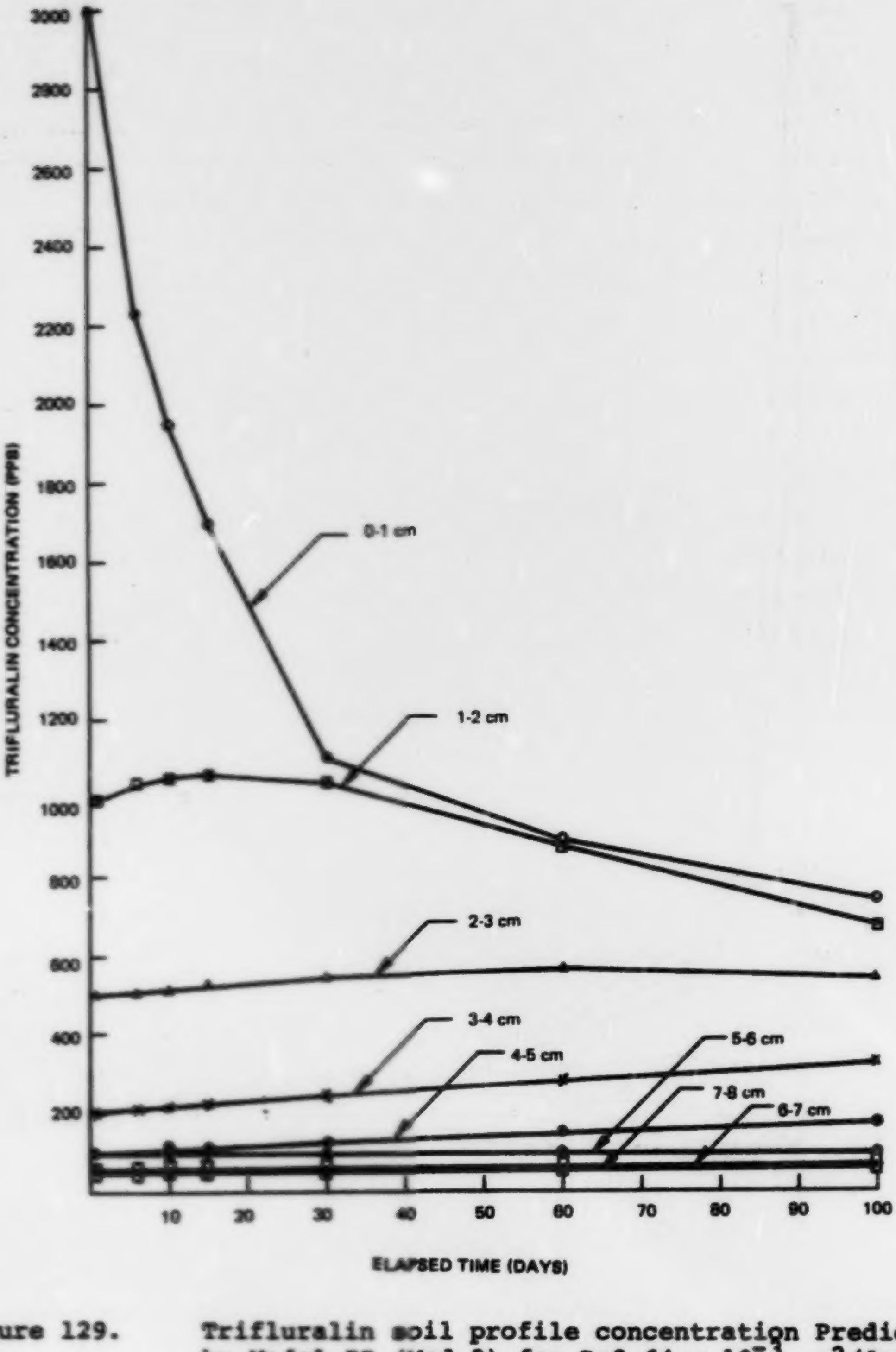


Figure 129. Trifluralin soil profile concentration Predicted by Model II (Mod 2) for $D=8.64 \times 10^{-3}$ cm^2/day

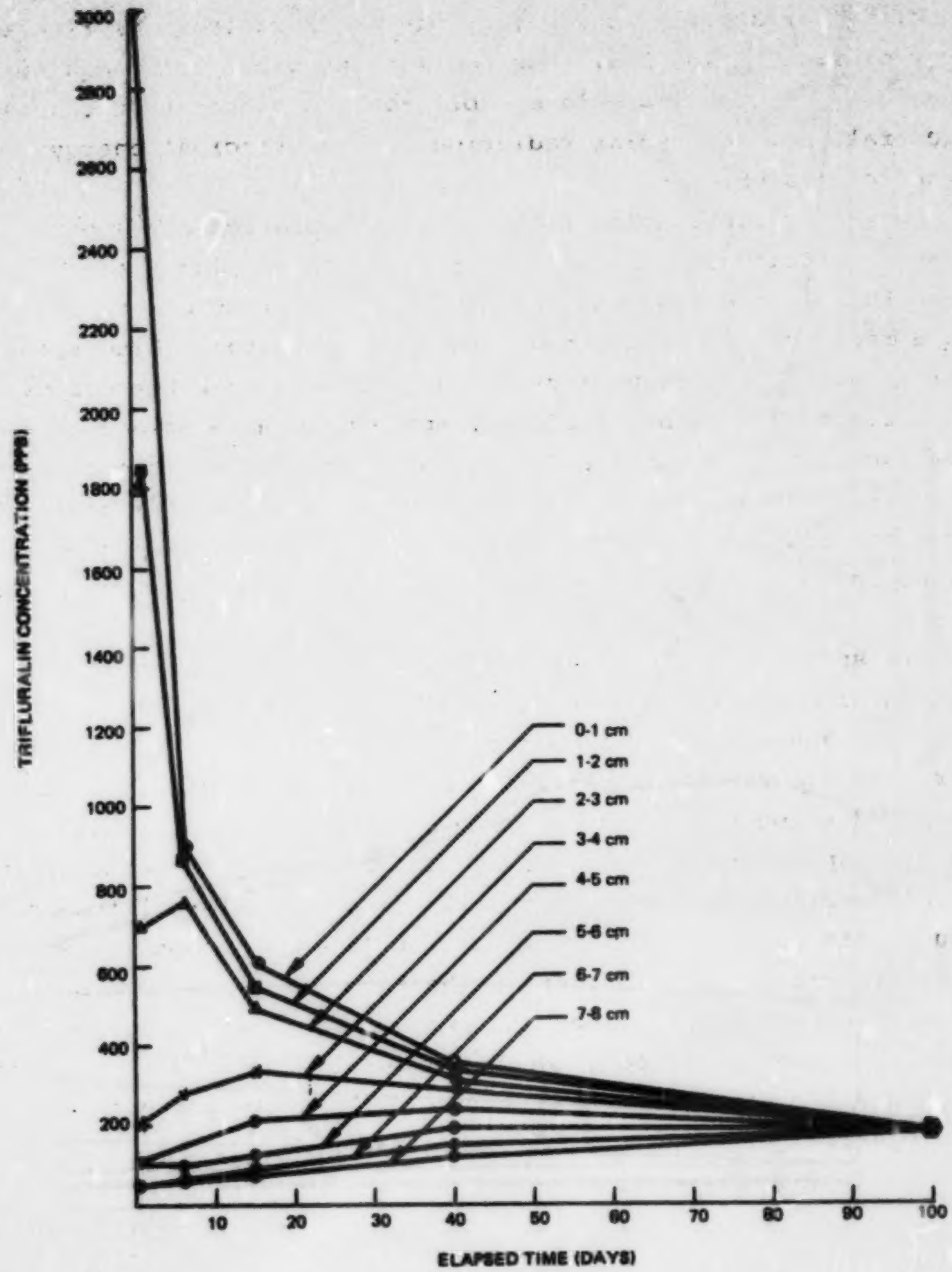


Figure 130. Trifluralin soil profile concentration predicted by Model II (Mod 2) for D=8.64 x 10^{-2} cm^2/day

ground. Alternatively, the energy may be drawn from the kinetic energy of water molecules, thus cooling the water until equilibrium with the atmosphere is established and evaporation ceases. In general, however, solar radiation is the principal energy source for evaporation.

The major controlling factors for evaporation are vapor pressure deficit and available energy, although wind speed, temperature of the evaporating surface, and purity of the water also affect the occurrence and rate of evaporation. Wind speed enables new parcels of unsaturated air to move over the evaporating surface. At higher surface temperatures more molecules of water can leave the surface due to their greater kinetic energy. The purity of the water affects the energy of vaporization required per unit weight of water. Salt for example, depresses the rate of evaporation about 3% in concentrations common to sea water.

Transpiration, the water loss from plants, is also a function of a vapor pressure gradient between the pressure of the air and that in the leaf cells. About 90% of the diurnal water loss occurs during daylight, because the water vapor is transpired through small pores (stomata) in the leaves which open in response to stimulation by light. Transpiration performs a vital function in the plant by affecting the internal transport of nutrients and the cooling of leaf surfaces. A complicating factor affecting transpiration is the interaction between soil moisture content and root development. If soil water is not replenished over a period of weeks, vegetation with deeper roots will transpire more than shallow rooted plants, other factors being equal.

When the moisture supply in the soil is limited, the factors cited above as controlling evaporation and transpiration are not as important, and the movement of the water through the soil is the controlling factor. In this event, the actual rate of evapotranspiration falls short of what is termed potential evapotranspiration, the rate of evapotranspiration which would occur if the supply of water to both the plants and the evaporating surface was unlimited. Analytical approaches compute only the potential evapotranspiration.

The relationship between these two terms - potential and actual - is a controversial one. At field capacity, which means maximum soil moisture content with free drainage, the ratio of actual to potential transpiration proceeds at the maximum potential rate. One view is that this potential rate is maintained until soil moisture content drops below some critical value, after which there is a sharp decrease in evapotranspiration. An alternate view maintains, however, that the rate decreases progressively with diminishing soil moisture. Recent experimental work has indicated that both views may be accurate for varying soil types and climatic conditions. The former applies in general to heavy soils in a relatively humid region, while the latter applies to sandy soils in arid regions.

There are two analytical approaches for computing potential evapotranspiration. The first approach is based upon aerodynamic principles and evaporation is regarded as due to turbulent transport of vapor by eddy diffusion. The second approach is based upon energy conservation and evaporation is regarded as one of the ways of degrading incoming radiation.

Mathematically the aerodynamic approach is expressed as:

$$E = f(\mu_2)\ (e_s - e_2) \qquad (71)$$

where E = evaporation

μ_2 = mean wind speed at height 2

e_s = saturation vapor pressure

e_2 = vapor pressure at reference height 2.

Equation (71) relates evaporation from large surfaces to the mean wind speed and the vapor pressure difference between the evaporating surface and the reference height 2. The function $f(\mu_2)$ has been postulated in simple form depending only on μ_2, and in complex forms which account for wind speed and turbulence.

The alternate approach is an energy balance about the evaporating surface. From fundamental principles of the conservation of energy, it follows that the net total of long and short wave radiation received at the surface is available for three processes. These three are the transfer of sensible heat to the atmosphere, the transfer of latent heat to the atmosphere (this energy is equal to the product of the latent heat of vaporization and the amount of evaporization), and the transfer of sensible heat into the ground. If the other variables can be determined, then the evaporization can be computed algebraically.

A number of methods have been developed to combine the aerodynamic and energy budget approaches, thereby eliminating certain measurement difficulties which each presents in an effort to obtain input parameters. This so called combination approach was suggested by H. L. Penman in 1948 and has been the major technique utilized since that time.[63] The actual Penman formulation has been modified more recently to include a term describing the stomata resistance as well as to correct some empiricism used by Penman in his original approach. C. H. M. Van Bavel[64] offered both changes to the Penman formulation as well as experimental verification of his own formulation in 1966.[64] Van Bavel's combination approach has been widely used since that time.

Three major assumptions are made when using a combination approach to compute potential evapotranspiration: (1) the assumption that the vertical divergence of the fluxes between surfaces and point of measurement, z is negligible, (2) the assumption that the turbulent transfer coefficients for water vapor and sensible heat are substantially equal and (3) the assumption that the value of Δ/γ, $(de_s/\gamma\ dT)$ can be taken at the temperature T_z rather than at the average of the unknown surface temperature T_s and the elevated air temperature T_z.

The evapotranspiration model used in the simulation structure utilizes the Penman combination approach with the Van Bavel modifications. Evapotranspiration is computed as:

$$E = \frac{1}{\rho_w L} \frac{\left(\frac{\Delta}{\gamma} H + \frac{\rho_a C_p d_a}{\gamma\ \tau_a}\right)}{\frac{\Delta}{\gamma} + 1 + \frac{\tau_s}{\tau_a}}$$

where E = potential evapotranspiration (cm/sec)

ρ_w = density of water (g/cm^3)

L = latent heat of vaporization (cal/g)

Δ = slope of the saturation vapor pressure versus temperature curve (mb/°C)

γ = psychrometric constant (mb/°C)

H = net sum of radiative flux, soil heat flux, heat storage changes in vegetation or ponded water and photosynthetically used energy not including the latent heat (LE) and the sensible heat.

ρ_a = density of moist air
C_p = specific heat at constant pressure of air
d_a = vapor pressure deficit - the difference between the saturation vapor pressure at a given temperature and the actual vapor pressure
τ_a = atmospheric resistance to diffusion computed as:

$$\tau_a = \frac{C_1^2}{\mu_2}\left(\ln \frac{z_2}{z_1}\right)^2 \qquad (73)$$

where C_1 = von Karman constant
μ_2 = wind speed at height 2
z_2 = height above the ground where meteorological variables are determined
z_1 = roughness parameter - empirically derived to account for the affect of vegetation on the flow fields about the evaporation surface
τ_s = surface and stoma resistance to diffusion - a parallel combination of all the separate resistances to moisture flux through the leaves and soil surface - determined empirically - varies seasonally according to the availability of moisture

Evapotranspiration Model Inputs

There are three types of inputs for computation of the amount of evapotranspiration:

1. constants which have fixed value

2. parameters having a range of potential values which are chosen with regard to the particular characteristics of the evapotranspiration setting such as crop type and size

3. climatic variables which vary as a function of the daily, even hourly situation.

In the first category, constant values for ρ_w, L, γ, ρ_a, C_p, and C_1 are used for all computations of potential evapotranspiration. τ_s and z are both functions of the vegetative surface and as such are chosen from experimental reference data prior to each computation. Δ and d_a are functions of the temperature of the atmosphere at a specific height above the surface and are read and computed from tables stored within the simulation structure. Experimental field data required for each potential evapotranspiration prediction then includes air temperature, wind velocity, relative humidity, barometric pressure, and the height above the ground where they each were measured. Solar radiation is calculated as a function of latitude and the time of year.

Sensitivity Analyses

Precise diurnal measurements of all the aforementioned variables are not available for all situations and approximate values must be substituted. In order to assess the sensitivity of the model to the precise values of the various parameters, a series of sensitivity runs were performed. Each variable was permitted to vary over a range of typical values in order to ascertain the effect of that permutation on the computed evapotranspiration value. Each variable's relationship with that value is depicted graphically in Figures 131 to 136. In addition, a sensitivity coefficient was computed for each variable as % variation/% change in potential evapotranspiration over the entire range of permutation to indicate numerically the relative sensitivity of the variables. Using this approach the most sensitive variable requiring the most precise determination is the net solar radiation followed in decreasing order of importance by the relative humidity, surface resistance, roughness parameter from 1-20, temperature, wind velocity, and roughness parameter from 0-1.

Sensitivity to Net Solar Radiation (H)

The graph illustrating the effect of changing net solar radiation values on final evapotranspiration is linear, indicating a direct proportionality (Figure 131). As noted above, the sensitivity analysis indicates the value for net solar radiation to be the most critical, raising concern over choice of its value. Two types of measurements are currently being made to determine net solar radiation: one direct measurement using a Fritchen type transducer, and one indirect using an Eppley Block and White Pyronometer. Sample 1973 data indicates differences by as much as 20% in these two types of measurement. In addition to the measurement anomalies, using an experimental value of net solar radiation neglects energy used for heat storage and photosynthesis. As H is increased by 100%, potential evapotranspiration increases by 167% with a corresponding sensitivity coefficient of 0.60.

Sensitivity to Relative Humidity h

The relative humidity h is another important meteorological variable to which potential evapotranspiration is extremely sensitive. The calculation of the vapor pressure deficit, $d_a = e_s - e_z$, involves the relative humidity, as $d_a = e_s(1-h)$. As h is increased by 300%, potential evapotranspiration decreases by 48% (Figure 132). The corresponding sensitivity coefficient is -0.159. Field measurements of relative humidity are straightforward and should not produce significant errors in the prediction of potential evapotranspiration.

Sensitivity to Surface Resistance

The surface resistance factor was varied over its range for all situations from mature alfalfa to bare soil to prime forest. While it is an important variable, its value can be chosen from the data of Szeicz,[65] et al to conform to the particular situation and thus should not produce large errors. As τ_s is increased from .1 to 1.6, E decreases from 0.52 to 0.42 mm/hr (Figure 133).

Sensitivity to the Roughness Parameter

The roughness parameter z_1 was varied in two steps: from 0 to 1, and 1-20 to minimize distortion at the lower range. Values of z_1 between 0 and 1 are associated with open water, wet soil, and mown grass, whereas values greater than 1 are associated with alfalfa (1.4), long grass (4-9), maize (2-22), sugar cane (4-9), orange groves (50), and pine forests (65-300)[24]. As z_1 is changed from wet soil (0.02) to 300 cm, maize (22) potential evapotranspiration increases from 0.4 mm/hr to 0.9 mm/hr (Figures 134 and 135).

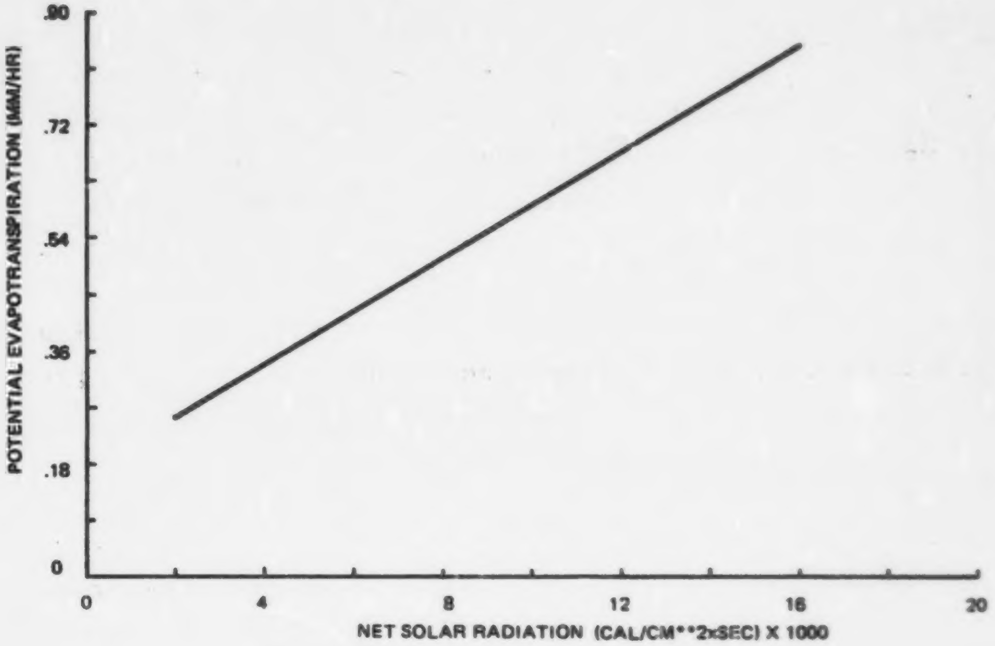


Figure 131. Potential evapotranspiration model sensitivity to net solar radiation

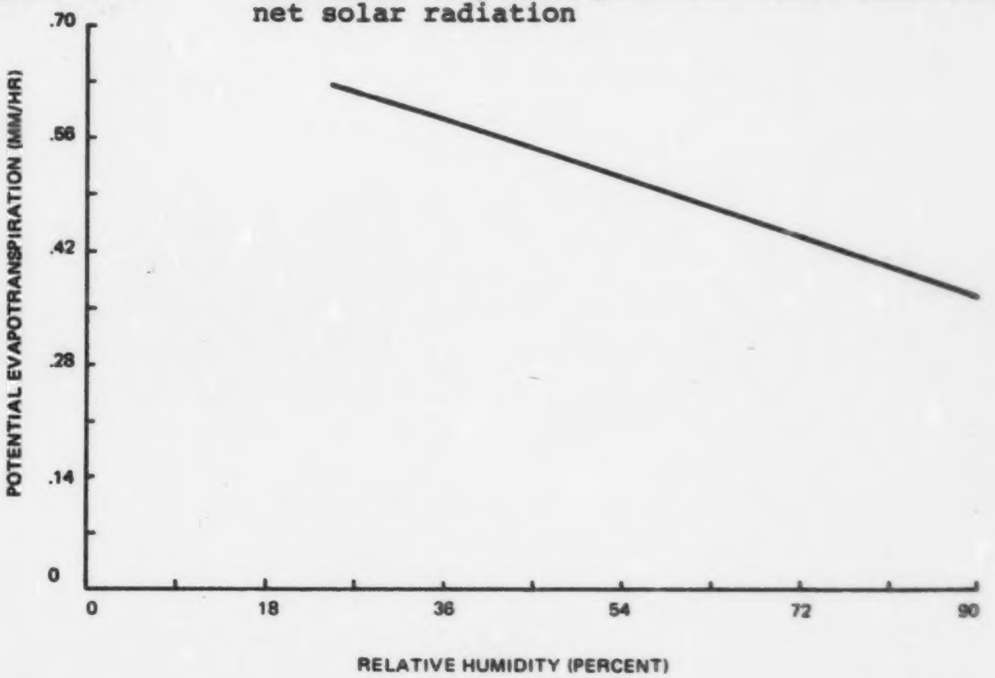


Figure 132. Potential evapotranspiration model sensitivity to relative humidity

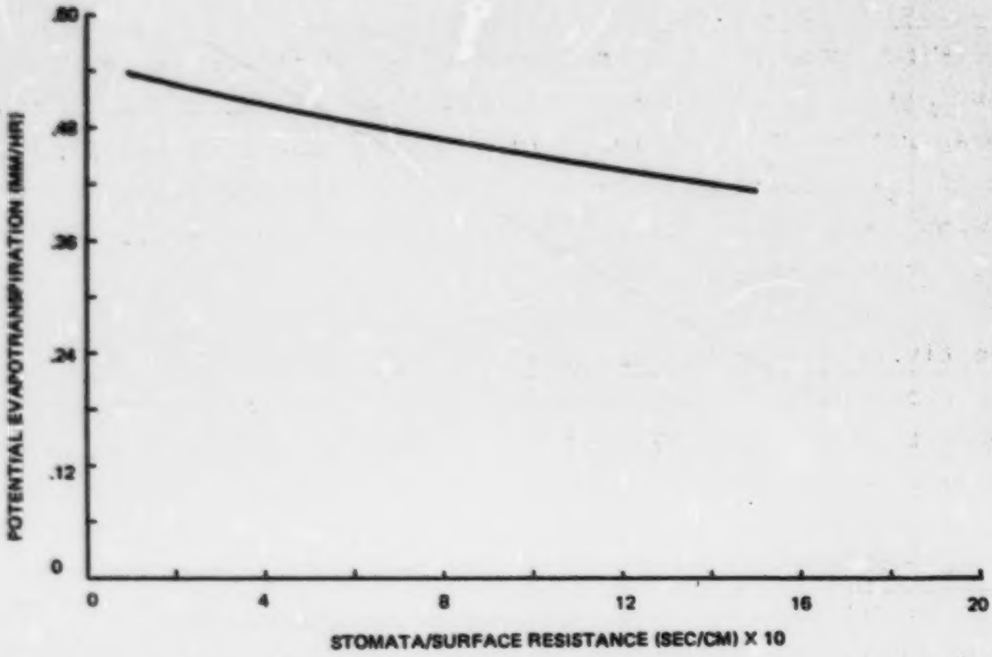


Figure 133. Potential evapotranspiration model sensitivity to stomata/surface resistance τ_s

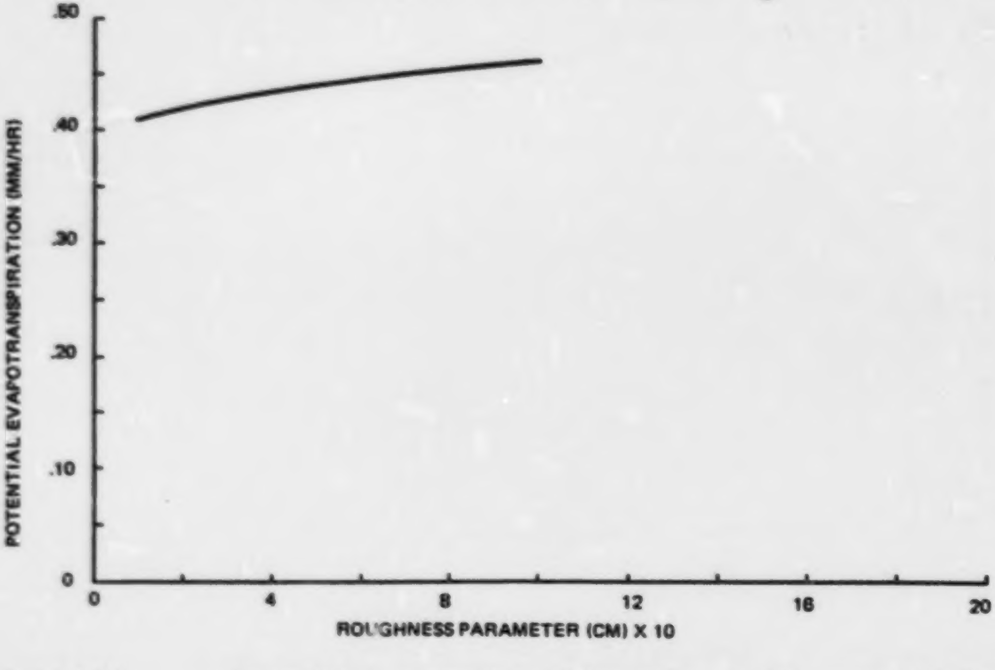


Figure 134. Potential evapotranspiration model sensitivity to roughness parameter z_1 between 0 and 1 cm

Sensitivity to Wind Speed

Wind speed μ_2 is in the denominator of the equation for calculating τ_a the atmospheric resistance to diffusion. Evapotranspiration, E, contains τ_a in both the numerator and denominator if τ_s is greater than zero. Because the dependency of τ_s on wind speed is not known, sensitivity to μ was evaluated with τ_s= zero (Figure 136).

Sensitivity to Air Temperature

Evapotranspiration potential increases linearly with temperature (Figure 137) and is an important variable in making accurate predictions.

Sensitivity to the Height of Meteorological Measurements - z_2

The ratio of z_2 to z_1 appears in the calculation of τ_a Again τ_a is in both the numerator and denominator of the equation for E, and hence, the effect on E is not straightforward. As z_2 increases beyond 60 cm, E decreases to a nearly constant level as the corresponding terms approach zero (Figure 138).

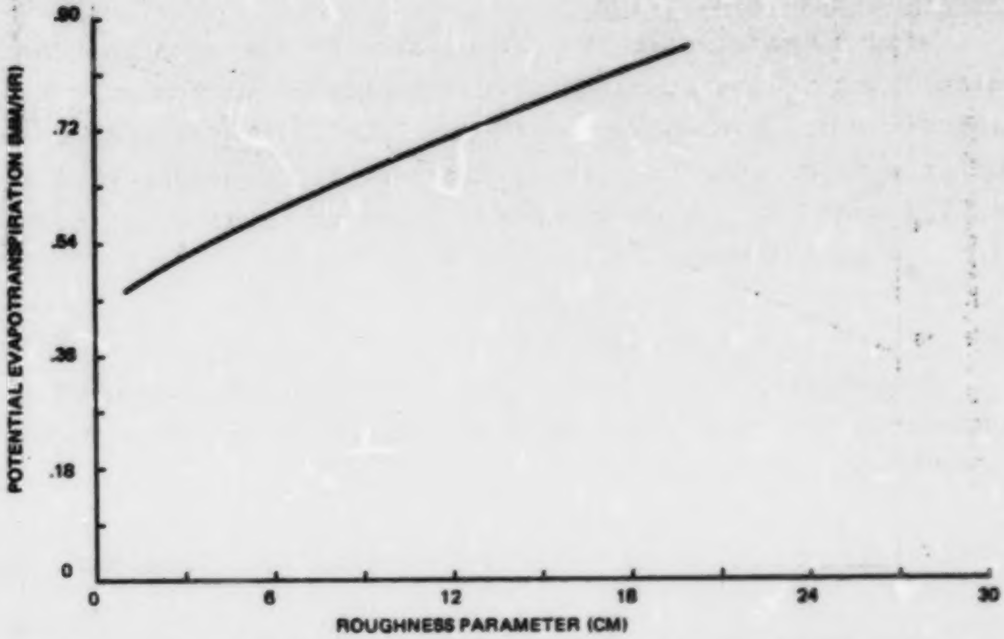


Figure 135. Potential evapotranspiration sensitivity to roughness parameter z_1

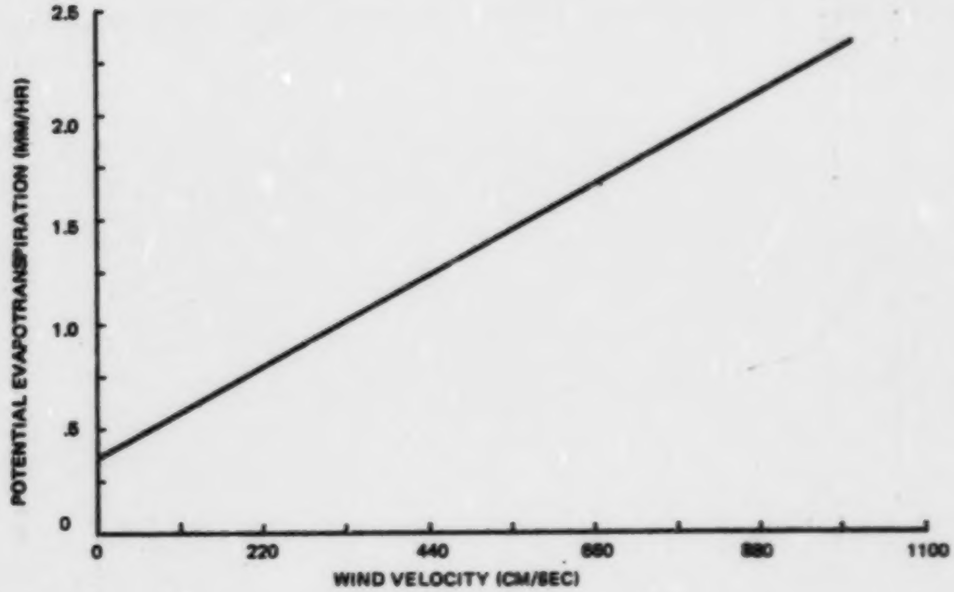


Figure 136. Potential evapotranspiration model sensitivity to wind speed

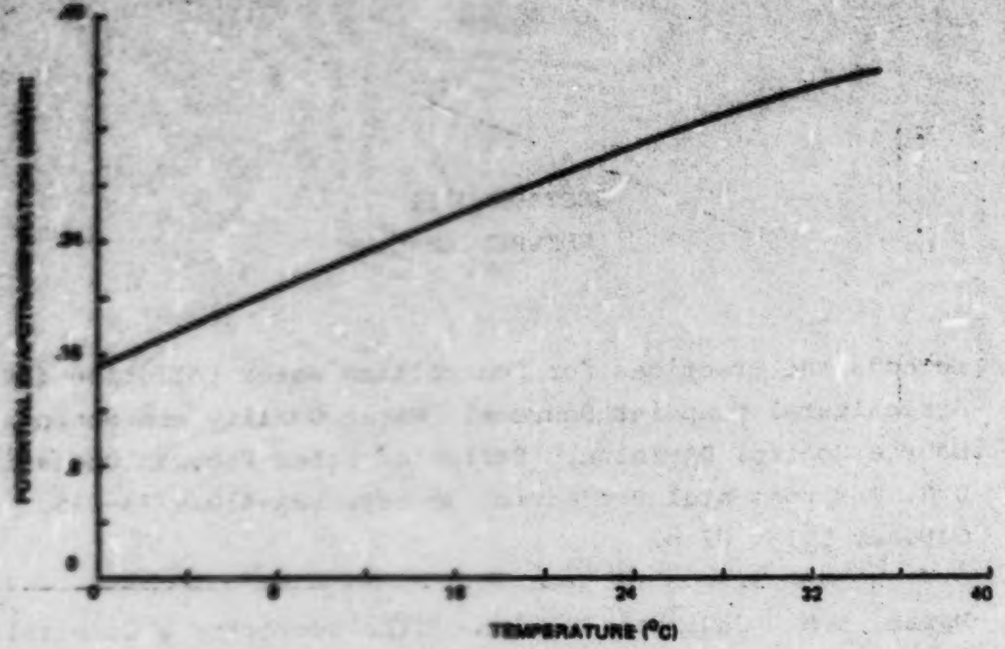


Figure 137. Potential evapotranspiration model sensitivity to air temperature

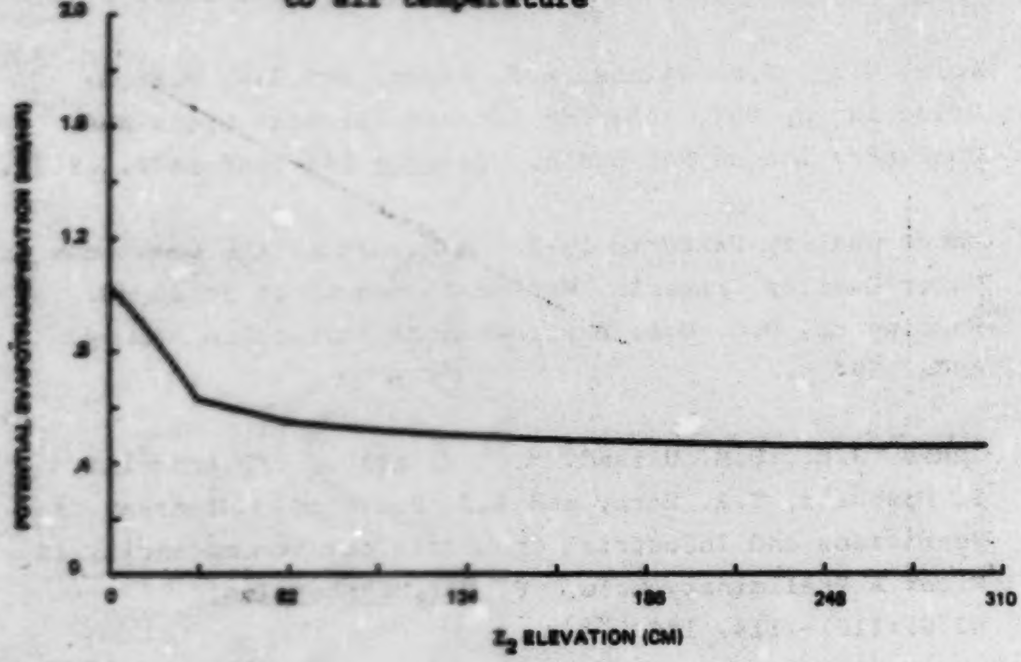


Figure 138. Potential evapotranspiration model sensitivity to height (Z_2) of meteorological measurements

SECTION VIII
REFERENCES

1. Methods and Practices for Controlling Water Pollution from Agricultural Nonpoint Sources. Water Quality and Nonpoint Source Control Division. Office of Water Program Operations, U.S. Environmental Protection Agency. EPA-430/9/73-015, October 1973. 82 p.

2. Myrak, E.M., Chairman, Report of the Secretary's Commission on Pesticides and Their Relationship to Environmental Health. Government Printing Office, Washington, D.C. 1969. 677p.

3. Dale, W.E., T.B. Gaines, W.J. Hayes, and G.W. Pearce. Poisoning by DDT: Relation Between Clinical Signs and Concentration on Rat Brain. Science 142:1474-1476,(1963).

4. Water Quality Criteria 1972. A Report of the Committee on Water Quality Criteria, National Academy of Sciences. Washington, D.C. U.S. Environmental Protection Agency. 1972. 594 p.

5. Innes, J.R., B.M. Ulland, M.G. Valario, L. Petrucelli, L. Fishbein, E.R. Hart, and A.J. Pallotta. Bioassay of Pesticides and Industrial Chemicals for Tumorogencity in Mice: A Preliminary Note. F. Nat. Cancer Inst. 42(6):1101-1114, 1969.

6. Tarjan, R., and T. Kenneny. Multigeneration Studies on DDT in Mice. Ed. Cosmet. Toxicol. 7:215, 1969.

7. Lehan, A.J. Summaries of Pesticide Toxicity. Association of Food and Drug Officials of the U.S. Topeka, Kansas. pp 1-40. 1965.

8. Durham, W.F. and W.J. Hayes. Organic Phosophorus Poisoning and Its Therapy. Arch. Environ. Health 5:21-47, 1962.

9. Environmental Quality: The Second Annual Report of the Council on Environmental Quality. U.S. Government Printing Office, Washington, D.C. 1971. 223-225p.

10. 7 U.S.C. Federal Environmental Pesticide Control Act, Sec. 136ff (1972).

11. 33 U.S.C., Federal Water Pollution Control Act, Sec. 1251ff (1972).

12. 21 U.S.C., Federal Food, Drug, and Cosmetic Act, Sec. 301ff (1938).

13. Bailey, G.W., R.R. Swank, and H.P. Nicholson. Predicting Pesticide Runoff from Agricultural Land: A Conceptual Model. J. Environ. Qual. 3:95-102, 1974.

14. Bailey, G.W., A.P. Barnett, W.R. Payne, Jr., and C.N. Smith. Herbicide Runoff from Four Coastal Plain Soil Types. Southeast Environmental Research Laboratory and the Southern Piedmont Conservation Research Center. EPA-660/2-74-017. NERC U.S. Environmental Protection Agency, Corvallis, Oregon. 1974.

15. U.S. Hydrology Staff. Field Manual for Research in Agricultural Hydrology. U.S. Department of Agriculture Handbook 224. 1962.

16. Fleming, W.G., and R.A. Leonard. Water-Sediment Splitter for Runoff Samples Containing Course-Grained Sediment. *Soil Science Soc. Amer. Proc.* 37:961-962, 1973.

17. Payne, W.R., Jr., J.D. Pope, Jr., and J.E. Benner. An Integrated Method for Paraquat, Diphenamid, and Trifluralin in Soil and Runoff from Agricultural Land. *J. Agr. Food Chem.* 22(1):79, Jan-Feb 1974.

18. Pope, J.D. Jr., and J.E. Benner. The Determination of Paraquat Residues in Soil and Water. *Journal of Offical Analytical Chemists.* 57(1):51-54, 1974.

19. Crawford, N.H., and A.S. Donigian, Jr. Pesticide Transport and Runoff Model for Agricultural Lands. Hydrocomp. U.S. Government Printing Office, Washington, D.C. EPA-660/2-74-013. U.S. Environmental Protection Agency, Washington, D.C. December 1973. 205 p.

20. Bode, L.E., C.L. Day, M.R. Gebhardt, C.E. Goering. Prediction of Trifluralin Diffusion Coefficients. *Weed Science.* 21(5): 485-489. 1973.

21. Scott, H.D. and R.E. Phillips. Diffusion of Selected Herbicides in Soil. *Soil Science Soc. Amer. Proc.* 36:714-719, 1972.

22. Carter, G.E. and N.D. Campter. Soil Enrichment Studies with Trifluralin. *Weed Science* 23:71-74, January 1975.

23. Kazeman, R.G., Modern Hydrology, Harper and Row, New York (1972).

24. Eagleson, P.S., Dynamic Hydrology, McGraw-Hill, San Francisco, Calif. (1970).

25. Smith, G.D., Numerical Solution of Partial Differential Equations, 1965.

26. Hanks, R.J. and S.A. Bowers. Numerical Solution of the Moisture Flow Equation for Infiltration into Layered Soils. Soil Science Sec. Amer. Proc. 26:530-539, 1962.

27. Philip, J.R. Evaporation and Moisture and Heat Fields in the Soil. J. Meteorology. 14:4, August 1957.

28. Bruce, R.R., Hydraulic Conductivity Evaluation of the Soil Profile from Soil Water Retention Relations. Soil Science Soc. Amer. Proc. 36:555-561, 1972.

29. Murota, A., and M. Hashino. Studies of a Stochastic Rainfall Model and It's Application to Sediment Transportation. Osaka University. Osaka, Japan. Tech. Rep. 19. 1969. p 231-247.

30. Woolhiser, D.A., and P. Todonivic. A Stochastic Model of Sediment Yield for Ephemeral Streams. Proc. USDA-IASPS Symposium on Statistical Hydrology. U.S. Department of Agriculture Miscellaneous Publications in Press. 1974.

31. Woolhiser, D.A., and J.A. Liggett. Unsteady, One-Dimensional Flow Area Plane - The Rising Hydrograph. Water Resource Research. 4(6):1179-1187, 1968.

32. Meyer, L.D., and W.H. Wischmeier. Mathematical Simulation of a Process of Soil Erosion by Water. Trans. ASAE. 12(6):754-762, 1969.

33. Foster, G.R., Private Communications.

34. Foster, G.R., and L.D. Meyer. Mathematical Simulation of Upland Erosion Using Fundamental Erosion Mechanics. Presented at Sediment Yield Workshop at Oxford, Mississippi. November 1972.

35. Foster, G.R., and L.D. Meyer. A Closed-Form Soil Erosion Equation for Upland Areas. Sedimentation Symposium to Honor Professor Hans Albert Einstein. Shen, H.W. (ed.). Fort Collins, Colorado State University., 1972. p 12-1 to 12-19.

36. Bennett, J.P. Concepts of Mathematical Modelling of Sediment Yield. Water Resources Research. 10(3):485-492, 1974.

37. Yalin, Y.S. An Expression for Bed-Load Transportation. Journal of the Hyd. Div., Proc. ASCE. 89(HY3):221-250, 1963.

38. Rowlison, D.L., and G.L. Martin. Rational Model Describing Step Erosion. Journal of Irrigation and Drainage Division, Proc. ASCE. 97(IR1):39-50, March 1971.

39. Eagleson, Peter S. Dynamic Hydrology. McGraw-Hill. 1970.

40. Foster, G.R., L.. Huggins, and L.D. Meyer. Simulation of Overland Flow on Short Field Plots. Water Resource Research. 4(6):1179-1187, 1968.

41. Moldenhauer, W.C., and D.C. Long. Influence of Rainfall Energy on Soil Loss and Infiltration Particles:I. Effect Over a Range of Texture. Soil Science Soc. Amer. Proc. 28(6): 813-817, 1964.

42. Rifai, M.N.E., W.J. Kaufman, and D.K. Todd. Dispersion Phenomena in Laminar Flow Porous Media. Sanitary Eng. Res. Lab. and Div. C.E. Report 3. University of California, Berkeley. 1956.

43. Day, P.R., and W.M. Forsythe. Hydrodynamic Dispersion of Solute in the Soil Moisture Stream. Soil Science, Soc. Amer. Proc. 21:477-480, 1958.

44. Biggar, J.W., and D.R. Nielsen. Miscible Displacement: I. Behavior of Tracers. Soil Science Soc. Amer. Proc. 26:125-128, 1962.

45. Rose, D.A. and J.B. Passioura. The Analysis of Experiments on Hydrodynamic Dispersion. Soil Science 3:252-257, 1971.

46. Biggar, J.W. and D.R. Nielsen. Miscible Displacement: V. Exchange Process. Soil Science Soc. Amer. Proc. 27;623-627, 1963.

47. Kay, B.O. and D.E. Elrick. Adsorption and Movement of Lindane in Soils. Soil Science 104:314-322, 1967.

48. Huggenberger, F.V. Letey, and W.J. Farmer. Observed and Calculated Distribution of Lindane in Soil Columns as Influenced by Water Movement. Soil Science Soc. Amer. Proc. 36:544-548, 1972.

49. Davidson, J.M., G.H. Brusewitz, D.R. Baker, and A.L. Wood. Use of Soil Parameters for Describing Pesticide Movement Through Soils. Project No. R-800364. Environmental Protection Agency, Washington, D.C. August 1974. 149p.

50. Chaudhari, N.M. An Improved Numerical Technique for Solving Multidimensional Miscible Displacement Equations. Soc. Petrol. Eng. J. 11:277-278, 1971.

51. Moe, P.G. Kinetics of the Microbial Decomposition of the Herbicides IPC and CIPC. Environmental Science and Technology. 4(50):429-431, 1970.

52. Burshel, P. and V.H. Freed. The Decomposition of Herbicides in Soil. Weeds. 7(2):157-161, 1959.

53. Schultz, D.P. and B.G. Tweedy. Uptake and Metabolism of N-N-Dimenthyl-2,2-Diphenylacetamide in Resistant and Susceptible Plants. J. Agr. Food Chem. 19(1):36-39, 1971.

54. Freed, V.H., R.L. Zimdahl, M.L. Montgomery, and W.R. Furtick. The Degradation of Triazine and Uracil Herbicides in Soil. *Weed Research* 10(1):19-26, 1970.

55. Personal Communications with Dr. W.C. Steen, Fall 1974.

56. Spencer, W.F., M.M. Claith, and W.J. Farmer. Vapor Density of Soil-Applied Dieldrin as Related to Soil-Water Content, Temperature and Dieldrin Concentration. *Soil Science Soc. Amer. Proc.* 33:509-511, 1969.

57. Shearer, R.C., J. Letey, W.J. Farmer, and A. Klute. Lindane Diffusion in Soil. *Soil Science Soc. of Amer. Proc.* 37(2):189-193, March-April 1973.

58. Farmer, W.J., K. Igue, W.F. Spencer, and J.P. Martin. Volatility of Organochlorine Insecticides from Soil: I. Effect of Concentration, Temperature, Air Flow Rate, and Vapor Pressure. *Soil Sci. Soc. Amer. Proc.* 36:443-447, 1972.

59. Igue, K., W.J. Farmer, W.F. Spencer, J.P. Martin. Volatility of Organochlorine Insecticides from Soil: II. Effect of Relative Humidity and Soil Water Content on Dieldrin Volatility. *Soil Sci. Soc. Amer. Proc.* 36:447-450, 1972.

60. Farmer, W.J., K. Igue, and W.F. Spencer. Effect of Bulk Density on the Diffusion and Volatilization of Dieldrin from Soil. *J. Environ. Qual.* 2:107-109, 1973.

61. Mayer, R., J. Letey, and W.J. Farmer. Models for Predicting Volatilization of Soil-Incorporated Pesticides. Soil. Sci. Soc. Amer. Proc. 38:563-567, 1974.

62. Carslaw, H.S., and J.C. Jaeger. Conduction of Heat in Solids, Second Edition, Oxford University Press. 1959.

63. Penman, H.L. Natural Evaporation from Open Water. Proc. Roy. Soc., London, 1948. p. 120-145.

64. Van Bavel, C.H.M., Potential Vaporation: The Combination Concept and Its Experimental Verification. Water Resources Research. 2:455-467, 1966.

65. Szeicz, G., G. Endrödi, and S. Jajchman. Aerodynamic and Surface Factors in Evaporation. Water Resources Research. 5(2):380-394, 1969.

APPENDIX A
USER'S GUIDE TO SCRAM

SCRAM was programmed to allow the user flexibility through the use of sequential data input and namelist data inputs. Table A-1 lists the program job control language set up. The user needs to set up a library with the program module. To the cards listed in Table A-1, the user must supply the library data set name, sequential data input and namelist input. Table A-2 describes the sequential data required by SCRAM including rain history and meteorology. This data is required for every event to be simulated. Table A-3 lists and describes the elements in the namelist input option. By selecting the proper options and supplying the proper parameter values, the user is able to run any event or sequence of events he desires.

User's Guide to SCRAM (Continued)

Table A-1. SCRAM JCL SET UP

INPUT DESCRIPTION

PROGRAM JOB CONTROL LANGUAGE SETUP

```
//   JOB
//   EXEC GOSTEP,LIB='Your Library Name'
//GO.FT11F001   DD   UNIT=SYSDA,SPACE=(TRK,(1,1))
//GO.FT12F001   DD   UNIT=SYSDA,SPACE=TRK,(1,1))
//GO.FT04F001   DD   *
     (Sequential Data Input)
//GO.SYSIN      DD   *
  &PESTI
     (Namelist Input Data)
  &END
//
```

User's Guide to SCRAM (Continued)

Table A-2. SEQUENTIAL DATA INPUT

RAINFALL CARDS

Card 1 - Header

Col 1-4 - 'RAIN'
Col 11-4 - Units flag for Rain Gauge
0 = cm
1 = mm
2 = m
3 = in
4 = ft

Card 2 - Number of watershed zones or subplots
col 1-5 NZN (I5)

Card 3 - Multiplying factors for rainfall rate on each zone

Col 1-80 - RMF (I), I = 1, NZN
[IF RMF(I) = 1.0 program 13 is the same as ESL 967. CONTM]
[If RMF(I) = -1.0, user must specify raingauge cards for each zone]

Cards 4,5,6, - Raingauge data cards

Col	Description	
1-4	Year	May be Omitted if Same as Previous Card
6-7	Month	
9-10	Day	
12-13	Hour	
15-16	Minute	
18-19	Second	
21-32	Rain Gauge Reading	

User's Guide to SCRAM (Continued)

Card 2 - Multiplying factors for each zone

Col 1-4 = EMF(1) (F4.0)

Col 5-8 = EMF (2)

: :
: EMF(NZN)
Col 77-80 EMF(20)

If all EMF(i) = 1.0 program runs as ESL 967. CONTM

Cards 3,4,5. . . Environmental Data

Col		Description
1-19	F12.0	Data - Same as Rain Cards
23-32		Wind Velocity
33-44		Air Temperature
45-56		Cloud Cover
57-68		Barometric Pressure
69-80		Relative Humidity

Table A-2. SEQUENTIAL DATA INPUT (continued)

EPA WEATHER DATA CARDS

Card 1 - Header

Col 1-4 - 'DAYS' or 'NITE' Indicate Whether Data is for Day or Night. (Day Value Used if No Night Data Specified.)

Col 12 - Units Flag for Wind Velocity
0 = cm/sec
1 = m/sec
2 = ft/sec
3 = mph
4 = knots

Col 14 - Units Flag For Air Temperature
0 = 'C
1 = °F

Col 16 - Units Flag For Cloud Cover
0-10 Scale

Col 18 - Units Flag for Barometric Pressure
0 = mb
1 = atmospheres
2 = PS1

Col 20 - Units Flag for Relative Humidity
0 = Fractional Hunidity
1 = Percent

Table A-3. NAMELIST INPUT DATA

ARRAY/ DIMENSION	ELEMENT	DEFAULT VALUE	DESCRIPTION
PLOTNM (5)	1–5	BLANKS	20 CHARACTER WATERSHED NAME
PESTNM (5)	1–5	BLANKS	20 CHARACTER PESTICIDE NAME
STARTM (6)	1–6	0	SIMULATION START TIME YEAR, MO, DAY, HR, MIN, SEC
ENDTM (6)	1–6	0	SIMULATION END TIME YEAR, MO, DAY, HR, MIN, SEC
PRINT (3)			OUTPUT PRINT INTERVALS, SEC
	1	100.	DURING RAIN
	2	600.	NO RAIN, SOIL MOIST
	3	86400.	NO RAIN, SOIL DRY
ELE2		0.	ELEVATION 2
RUFF		0.	ROUGHNESS PARAM.
SRES		0.	SURFACE RESISTANCE
DELGAM (121)			PARTIAL OF DELTA W.R.T. GAMMA
SVPRES (121)			SATURATION VAPOR PRESSURE
			} CONSTANTS USED BY EVAPOTRANSPIRATION MODEL
DHARAY (1520)			DHTAB TABLE INPUT
	I	0	SOIL TYPE NUMBER (1–10)
	I + 1	0	NUMBER POINTS IN ARRAYS (N)
	I + 2	0	N THETA VALUES
	I + 2 + N	0	N DIFFUSIVITY VALUES
	I + 2 + 2N	0	N PRESSURE HEAD VALUES
THETA (27, 20)	I, J	0	SOIL MOISTURE PROFILE
ZONES (14, 20)			WATERSHED ZONE DEFINITION
	1, I	0	SOIL TYPE NUMBER 1 = LT CLAY 2 = SERL LOAM 3 =
	2, I	0	AREA
	3, I	0	SLOPE, PERCENT
	4, I	0	LENGTH
	5, I	0	AVERAGE WIDTH
	6, I	0	BULK DENSITY
	7, I	0	NO. INCREMENTS (USED FOR SEDIMENT MODEL)
	8, I	0	NO. LAYERS (USED FOR INFILTRATION MODEL)
	9, I	0	LAYER THICKNESS
	10, I	0	MAXIMUM RUNOFF VELOCITY
	11, I	0	UNITS FLAG FOR AREA 0 = cm^2 1 = ft^2 2 = ACRES
	12, I	0	UNITS FLAG FOR LENGTH, WIDTH 0 = cm 1 = ft
	13, I	0	UNITS FLAG FOR LAYER THICKNESS, RUNOFF RATE 0 = cm, cm/SEC 1 = ft, ft/SEC
	14, I	0	UNITS FLAG FOR BULK DENSITY 0 = gm/cm^3 1 = lb/ft^3

Table A-3. NAMELIST INPUT DATA (Continued)

ARRAY/ DIMENSION	ELEMENT	DEFAULT VALUE	DESCRIPTION	
RUNOFF			ZONE RUNOFF DEFINITION	
(2, 4, 20)			(FOUR PAIRS PER ZONE)	
	1, I, J	0	ZONE TO WHICH RUNOFF GOES	
	2, I, J	0	PROPORTIONAL AMOUNT	
CON			PROGRAM CONSTANTS	
(50)	1	1.169E–3	MASDEN	
	2	582.	LTHEAT	USED BY
	3	6.1E–4	BOWEN	EVAPOTRANSPIRATION
	4	0.46	SHEATP	MODEL
	5	2.5	VONK	
	6	0	THRSH1 -- RAINFALL RATE THRESHOLD	
	7	0.100	THRSH 2 – SOIL MOISTURE THRESHOLD	
	8	1	WD – WEIGHT DENSITY (SEDI)	
	9	1	DTMIN – MINIMUM DELTA T IN SIMULATION	
	10		K	
	11		RHO	
	12		T	
	13		NEXP	CONSTANTS USED
	14		AB	BY ADDE
	15		CO	
	16		PULSE	
	17		DVS	
	18		D	
	19		ALIM	SEDIMENT LIMIT
	20		ALAT	LATITUDE OF SUBPLOT
	21		MSR	MAXIMUM SOLAR RADIATION
	22		KOPT	
	23		MOPT	
	24		TOPT	CONSTANTS
	25		TMAX	USED BY
	26		AK	DEGR
	27		BK	
	28		CANOPY COVER – USED IN ADJUSTMENT OF K3 - ST	
IOPT			PROGRAM CONTROL OPTIONS	
(50)	1	0	COLD START OPTION 0 = COLD START 1 = WARM START	
	2	0	≠0 TO PREPARE FOR WARM START	
	3	0	≠0 TO WRITE NAMELIST DATA	
	4	0	≠0 TO PRINT DHTAB ARRAYS	
	5	0	≠0 CARD PUNCH FOR CALCOMP PLOTS	
	6	0	≠0 TIME O/P FROM BALANC	
	7	0	≠0 O/P AT RAINFALL CHANGE TIMES	
	8	2	= NO READ – USED BY ADDE	
	9	1	= N # PRINTER – O/P	
	10	0	= 1 O/P EVERY CYCLE	
	11	0	≠0 DO NOT CALL DEGR IN MAIN	
	12	0	≠0 DO NOT CALL ADDE IN MAIN	
	13	0	≠0 DO NOT CALL VOLT IN MAIN	
	14	0	≠0 DO NOT O/P WHEN IDRY = 0	
	15	0	≠0 DO O/P AT PRINT (I) EXACTLY	
	16	0	≠0 DO VOLATILIZATION O/P ONLY	
ENG		0	NANOGRAMS PESTICIDE APPLIED (VOLT)	
ALFA		0	APPLICATION RATE (VOLT)	
DV (27, 20)		0	DIFFUSION COEFFICIENTS (VOLT)	
DIST (27, 20)		0	PESTICIDE PROFILE BY ZONE (VOLT)	

APPENDIX B

SCRAM PROGRAM LISTING

(FORTRAN IV, IBM 370)

- MASTER SCHEDULER
- ADDE
- BALANC
- DATEIN
- DATINTI
- DATOUT
- DEGRAD
- EVAP
- FILTR
- INPUT
- ITABLE
- NEWRAP
- OUTPLT
- OUTPUT
- PRNTTM
- RK
- RUNGE
- SED
- SEQDAT
- SETUP
- SIMPSN
- SOLAR
- VOLT
- VPRNT
- WATER

SCRAM Program Listing (Continued)

```
C
C
C   SIMULATION OF CONTAMINANT REACTIONS AND MOVEMENT (SCRAM)
C
C
C   PESTICIDE SIMULATION  PROGRAM ---MASTER SCHEDULER
C
      COMMON /TIMES/ TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,
     1      EPATM, PRINT(3), PROGDT(3), PESTM ,DATPL,DATMAT,DATHAR
      REAL*8 TOLD,TNEW,DT,DTOLD,TOUT,TSTPT,TSTOP,TRAIN,PIN,EPATM,PESTM
      REAL*8 DATPL,DATMAT,DATHAR
      EQUIVALENCE (PRINT(1),PINR),(PRINT(2),PINRO),(PRINT(3),PINDRY),
     1      (PROGDT(1),DTWET),(PROGDT(2),DTRO),(PROGDT(3),DTDRY)
C
      COMMON /WATERD/ NZN, RAINR(20),  THETA(27,20),THETN(27,20),CUMRO
     1      ,CUMFLT,DHTAB(50,4,10),NUMDH(10),RINF(20),CIT(20),VELC(27,20)
     2      ,Q(27,20),SUMAN,WATROT,SUMIN,ROR
      COMMON /SEDATA/ SUB(10,20),ADJLI(21)
C
      COMMON /CONST/ CON(50),IOPT(50),KPEST
      EQUIVALENCE (THRSH1,CON(6)),(THRSH2,CON(7))
      DIMENSION RAINO(20)
C
      CALL SETUP
      CALL SEQDAT
    1 CALL INPUT
      CALL DATINT
      CALL OUTPUT(1)
C   CALCULATE NEXT OUTPUT CALL
      TOUT =(IDINT(TSTRT/PIN)+1.D0)*PIN
      IDRY = 1
C   START MAIN LOOP
   10 CONTINUE
      DO 11 I=1,NZN
      IF (RAINR(I) .GT. THRSH1) GO TO 30
   11 CONTINUE
C   CHECK FOR RUNOFF
      IF (IDRY .EQ. 0) GO TO 14
      DO 12 I=1,NZN
      IF (THETA(2,I) .GT. THRSH2) GO TO 20
 12   CONTINUE
C   NO RUNOFF, NO RAIN
 14   PIN = PINDRY
      IDRY = 0
      TNEW = DMIN1(TRAIN,TOUT)
      IF(IOPT(15).EQ.0) TNEW=TRAIN
      IF (TNEW-TOLD .GT. DTDRY) TNEW = TOLD + DTDRY
      DT = TNEW-TOLD
      IF(TNEW.LT.TOUT) TOUT= (IDINT(TNEW/PIN)+1.D0) *PIN
      GO TO 25
C   RUNOFF PRESENT, NO RAIN
 20   PIN = PINRO
      IDRY = 1
      TNEW = DMIN1(TRAIN,TOUT)
```

SCRAM Program Listing (Continued)

```
      IF(IOPT(15).EQ.0) TNEW=TRAIN
      IF(TNEW-TOLD .GT. DTRO) TNEW = TOLD+DTRO
      IF(TNEW.LT.TOUT) TOUT= (IDINT(TNEW/PIN)+1.D0) *PIN
      CALL FILTA
      TNEW = TOLD+DT
      CALL SED
 25   IF (TNEW .GT. EPATH) CALL DATEPA
      CALL EVAP
      GO TO 40
C  RAINING
 30   PIN = PINR
      IDRY = 2
      TNEW = DMIN1(TRAIN,TOUT)
      IF(IOPT(15).EQ.0) TNEW=TRAIN
      IF (TNEW-TOLD .GT. DTWET) TNEW = TOLD + DTWET
      IF(TNEW.LT.TOUT) TOUT= (IDINT(TNEW/PIN)+1.D0) *PIN
      CALL FILTA
      TNEW = TOLD+DT
      IF (TNEW .GE. PESTN) KPEST = 1
      CALL SED
 40   IF (KPEST .EQ. 0) GO TO 41
      IF(IOPT(13) .NE.0) GO TO 51
      CALL VOLT
   51 IF(IOPT(11). NE. 0) GO TO 50
      CALL DEGRAD
  50  IF(IOPT(12).NE.0)  GO TO 41
      CALL ADDE (IDRY)
 41   CALL BALANC (IDRY,KPEST)
      TOLD = TNEW
      DTOLD = DT
      IF (TNEW .GE. TRAIN) GO TO 44
 42   IF (TNEW .LT. TOUT .AND. IOPT(10) .EQ. 0) GO TO 48
      IF(IOPT(14).EQ.0 .OR. IDRY. NE.0) CALL OUTPUT(2)
      TOUT =(IDINT(TNEW/PIN) + 1.D0)*PIN
      GO TO 48
 44   CONTINUE
      DO 13 I=1,NZN
   13 RAINO(I)= RAINR(I)
      CALL DATIN
      DO 15 I=1,NZN
      IF(RAINO(I).NE.0) GO TO 15
      IF(RAINR(I ).EQ.0) GO TO 15
      CALL OUTPUT(5)
      GO TO 45
   15 CONTINUE
   45 IF (IOPT(7) .EQ. 0) GO TO 42
      CALL OUTPUT(3)
      TOUT =(IDINT(TNEW/PIN)+1.D0)*PIN
 48   IF (TOLD .LT. TSTOP) GO TO 10
C  FINISHED
      CALL OUTPUT(4)
      CALL OUTPLT
      REWIND 11
      REWIND 12
```

SCRAM Program Listing (Continued)

```
      GO TO 1
      END
```

SCRAM Program Listing (Continued)

```
      BLOCK DATA
C
C
C  VARIABLES ARE INTIALIZED AND DEFAULT VALUES ARE SET IN THIS ROUTINE
C
      COMMON /INPUTD/ STARTM(6),ENDTM(6),PLOTNM(5),PESTNM(5),
     1     PESDAT(11),CROPDT(10),ZONES(14,20) ,RUNOFF(2,4,20)
C
      COMMON /CONST/ CON(50),IOPT(50),KPEST,NZPREV, NZERO
C
      COMMON /EVAPIN/ ELE2,DATA(5,20), DATAN(5,20),
     1                RUFF,SRES,DELGAM(121),SVPRES(121),VPRE2,VPDEF,
     2     ATRES,POEVAP,TOTVAP
C
      COMMON /TIMES/ TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,
     1     EPATM, PRINT(3), PROGDT(3), PESTM ,DATPL,DATMAT,DATHAR
      REAL*8 TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,EPATM,PESTM
      REAL*8 DATPL,DATMAT,DATHAR
C
      COMMON /WATERD/ NZN, RAINR(20),  THETA(27,20),THETN(27,20),CUMRO
     1     ,CUMFLT,DHTAB(50,4,10),NUMDH(10),RINF(20),CIT(20),VELC(27,20)
     2     ,Q(27,20),SUMRN,WATROT,SUMIN,ROR,RDT ,XUNRO
C
      COMMON /SEDATA/SUB(10,20),ADJLI(21),ADJLO(20),RNF(4,20),INF(4,20)
     1    ,SEDRAT,HECT,AK1(10),AK2(10),ST(10),ADJLL
     2    ,XADJLI
C
      COMMON /ADDATA/ C(27,20), S(27,20), KNT, SSS(27,20)
     1     ,DC(27), VEL(27), THETJ(27), D(27),KDES(27,20),CMAXUM(27,20),
     2     THETX,XMAX, H, KTIME,II, A, DENOM,DENAM,INDEX(20),INDEX1(20),
     3     ANT, AX, IISAVE, IGOR, NVAL(20),DESKRO, XPONT,KLEW1(20),DVST,
     4     THETAT, SUMC(27), SUMS(27),CUMAD, CUMDS,PTOT(20) ,C1(27,20)
     5     , VPAST(27,20),KSM(20),INTGER ,NOSTOP(20),ADRX,DSRX
     6     ,TOTAD,TOTDS,ZROC(27,20) ,CCL(27),SSL(27),TOT(27)
C
      COMMON /VOLTD/ ENG,ALFA,DV(27,20),DIST(27,20),IV1,PPB(27,20),
     1               DVS(27,20),P2
C
      DATA SUB /200*0./
      DATA ADJLI/21*0./  ,ADJLO/20*0./ ,SEDRAT/0./
      DATA AK1, AK2, ST/ 10*79.298, 10*.3418E-2, 10*8./
      DATA STARTM /6*0./
      DATA ENDTM /6*0./
      DATA PLOTNM /5*' '/
      DATA PESTNM /5*' '/
      DATA PESDAT /5*0., 1999., 1., 1., 3*0./
      DATA CROPDT/0.,1999.,1.,1.,1999.,1.,1.,1999.,1.,1. /
      DATA ZONES /280*.0/
      DATA RUNOFF /160*0./
      DATA PRINT /600.,600., 86400./
      DATA PROGDT /60., 900.,3600./
      DATA CON /1.168E-3, 582., 6.1E-4, 0.48, 2.5,
     1     1.E-5, 0.25, 1., 1.,
     2     0.4, 1.53, 0., 1., 2.5, 90., 13., 0., 0.1,
```

SCRAM Program Listing (Continued)

```
*     2., 33., .008,
*     .119676, .173599, 38.2344, 39.9065, -92.004, .032771,
*     .9, 22*0./
 DATA IOPT/7*0,2,1,41*0/
 DATA KPEST/0/
 DATA ELE2, RUFF, SRES /121.9, 0.02, 0.5/
 DATA TOTVAP /0./
 DATA DELGAM /
*   0.670,  0.690,  0.720,  0.740,  0.760,  0.790,  0.810,  0.840,
*   0.860,  0.690,  0.920,  0.940,  0.970,  1.000,  1.030,  1.060,
*   1.100,  1.130,  1.160,  1.200,  1.230,  1.270,  1.300,  1.340,
*   1.380,  1.420,  1.460,  1.500,  1.550,  1.590,  1.640,  1.680,
*   1.730,  1.780,  1.820,  1.880,  1.930,  1.980,  2.030,  2.090,
*   2.140,  2.200,  2.260,  2.320,  2.380,  2.450,  2.510,  2.580,
*   2.640,  2.710,  2.780,  2.850,  2.920,  3.000,  3.080,  3.150,
*   3.230,  3.310,  3.400,  3.480,  3.570,  3.660,  3.750,  3.840,
*   3.930,  4.030,  4.120,  4.220,  4.320,  4.430,  4.530,  4.640,
*   4.750,  4.860,  4.970,  5.090,  5.200,  5.320,  5.450,  5.570,
*   5.700,  5.830,  5.960,  6.090,  6.230,  6.370,  6.510,  6.650,
*   6.800,  6.950,  7.100,  7.260,  7.410,  7.570,  7.730,  7.900,
*   8.070,  8.240,  8.420,  8.600,  8.770,  8.960,  9.140,  9.330,
*   9.520,  9.720,  9.920, 10.100, 10.300, 10.500, 10.800, 11.000,
*  11.200, 11.400, 11.600, 11.900, 12.100, 12.300, 12.600, 12.800,
*  13.100/
 DATA SVPRES /
*   4.579,  4.750,  4.926,  5.107,  5.294,  5.486,  5.685,  5.889,
*   6.101,  6.318,  6.543,  6.775,  7.013,  7.259,  7.513,  7.775,
*   8.045,  8.323,  8.609,  8.905,  9.209,  9.521,  9.844, 10.176,
*  10.518, 10.870, 11.231, 11.604, 11.987, 12.382, 12.788, 13.205,
*  13.634, 14.076, 14.530, 14.997, 15.477, 15.971, 16.477, 16.999,
*  17.535, 18.085, 18.650, 19.231, 19.827, 20.440, 21.068, 21.714,
*  22.377, 23.060, 23.756, 24.471, 25.209, 25.964, 26.739, 27.535,
*  28.349, 29.184, 30.043, 30.923, 31.824, 32.747, 33.695, 34.667,
*  35.663, 36.683, 37.729, 38.801, 39.898, 41.023, 42.175, 43.355,
*  44.563, 45.799, 47.067, 48.364, 49.692, 51.048, 52.442, 53.867,
*  55.324, 56.810, 58.340, 59.950, 61.500, 63.130, 64.800, 66.510,
*  68.260, 70.050, 71.880, 73.740, 75.650, 77.400, 79.600, 81.650,
*  83.710, 85.850, 88.020, 90.240, 92.510, 94.860, 97.200, 99.650,
*102.090,104.650,107.200,109.860,112.510,115.280,118.040,120.920,
*123.820,126.810,129.820,132.950,136.080,139.340,142.600,145.990,
*149.380/
 DATA THETA /540*0./
 DATA THETN /540*0./
 DATA CUMRU /0./
 DATA CUMFLT /0./
 DATA SUMIN /0./
 DATA DHTAB /
* 6.00E-02, 8.00E-02, 1.00E-01, 1.20E-01, 1.40E-01, 1.60E-01,
* 1.80E-01, 2.00E-01, 2.20E-01, 2.40E-01, 2.60E-01, 2.80E-01,
* 3.00E-01, 3.20E-01, 3.40E-01, 3.60E-01, 3.80E-01, 4.00E-01,
* 4.20E-01, 4.40E-01, 4.60E-01, 4.80E-01, 5.00E-01, 27*0.,
* 1.00E-07, 1.00E-06, 6.00E-06, 1.00E-05, 3.00E-05, 5.30E-05,
* 7.30E-05, 9.00E-05, 1.50E-04, 3.00E-04, 4.30E-04, 6.00E-04,
* 7.00E-04, 8.00E-04, 9.00E-04, 9.50E-04, 1.00E-03, 1.30E-03,
```

SCRAM Program Listing (Continued)

```
* 1.60E-03, 1.20E-03, 2.00E-03, 7.00E-03, 1.00E-02, 27*0.,
*-6.00E 05,-9.00E 04,-4.00E 04,-1.00E 04,-7.00E 03,-4.70E 03,
*-2.00E 03,-1.00E 03,-8.00E 02,-6.80E 02,-5.70E 02,-4.50E 02,
*-3.30E 02,-2.20E 02,-1.00E 02,-9.00E 01,-7.70E 01,-6.00E 01,
*-5.00E 01,-4.00E 01,-2.00E 01,-1.00E 01, 0.0     , 27*0.,
*  50*0., 1800*0./
 DATA C,S,SUMC,SUMS/ 540*0., 540*0., 27*0., 27*0./
 DATA CUMAD, CUMDS /0.,0./
 DATA KNT/0/
 DATA VEL,NVAL/27*0., 20 *1 /
 DATA PTOT,C1/ 20*0.,540*0./
 DATA CMAXUM, VPAST , KSW, INTGER, IGOR /540*0., 540*0.,20*0,0,0/
 DATA NOSTOP/20*0/
 DATA KLEN1, INDEX,INDEX1 /20*1, 20*2, 20*2 /
 DATA RDT,ADJLL/2*0./
 DATA XUMRO/0./
 DATA TOTAD,TOTDS/2*0./
 DATA XADJLI/0./
 DATA  ZROC/540*0./
 DATA IV1, ENG, ALFA, DV/ 0,7000., 1.0, 540*0/
 DATA DIST /1.,26*0.,1.,26*0.,1.,26*0.,1.,26*0.,1.,26*0.,1.,26*0.,
*          1.,26*0.,1.,26*0.,1.,26*0.,1.,26*0.,1.,26*0.,1.,26*0.,
*          1.,26*0.,1.,26*0.,1.,26*0.,1.,26*0.,1.,26*0.,1.,26*0.,
*          1.,26*0.,1.,26*0.   /
 DATA NZPREV, NZERO/0,0/
 DATA CCL,SSL,TOT/27*0.,27*0.,27*0./
 END
```

```
      SUBROUTINE ADDE(IDAY)
C
      COMMON /WATERD/ NZN, RAINR, THETA(27,20),THETN(27,20),CUMRF
     1      ,CUMFLT,DHTAB(50,4,10),NUMDH(10),RINF(20),CIT(20),VELC(27,20)
     2      ,Q(27,20),SUMAN,WATROT,SUMIN,ROR
C
      COMMON /ADDATA/ C(27,20), S(27,20), KNT, SSS(27,20)
     1      ,DC(27), VEL(27), THETJ(27), B(27), KDES(27,20),CMAXUM(27,20)
     2 ,THETX,XMAX,H,KTIME,II,A,DENOM,DENAM,INDEX(20),INDEX1(20),
     3      ANT, AX, IISAVE, IGOR, NVAL(20),DESKRO, XPONT,KLEN1(20),DYST,
     4      THETAT, SUMC(27), SUMS(27),CUMAD, CUMDS,PTOT(20) ,C1(27,20)
     5      , VPAST(27,20),KSM(20),INTGER ,NOSTOP(20),ADRO,DSRO
      COMMON /CONST/ CON(50),IOPT(50)
      EQUIVALENCE (CON(12),T)
      EQUIVALENCE (NOREAD,IOPT(8))
C
      DO 10 I=1,NZN
      NOREAD=0
      IF(NVAL(I ).EQ.2) NOREAD=2
 10   CALL CONTAM(I,IDAY)
      DO 15 I=1,NZN
      IF(PTOT(I) .GT. .001)  RETURN
   15 CONTINUE
C
C  IF PESTICIDE IS GONE, IN MAIN
C                                 DO NOT CALL ADDE ----IOPT(12) NE  0
C                                 DO NOT CALL DEGR-----IOPT(11) NE  0
      IOPT(11)=1
      IOPT(12)=1
      RETURN
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE BALANC(IDRY,KPEST)
C
C  SUBROUTINE TO ACTUALLY MOVE WATER, SEDIMENT, AND PESTICIDE.
C  ALSO CALCULATES TOTAL AMOUNT OF WATER AND PESTICIDE TO CHECK
C  AGAINST PREVIOUS AMOUNT.
C
      COMMON /SEDATA/SUB(10,20),ADJLI(21),ADJLO(20),RNF(4,20),INF(4,20)
     1    ,SEDRAT,HECT,AK1(10),AK2(10),ST(10),ADJLL
     2    ,XADJLI
C
      COMMON /WATERO/ NZN, RAINR(20), THETA(27,20),THETN(27,20),CUMRO
     1      ,CUMFLT,DHTAB(50,4,10),NUMDH(10),RINF(20),CIT(20),QTOT(27,20)
     2      ,Q(27,20),SUMRN,WATROT,SUMIN,ROR,RDT ,XUMRO
C
      COMMON /TIMES/ TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,
     1      EPATM, PRINT(3), PROGDT(3), PESTM ,DATPL,DATMAT,DATMAR
      REAL*8 TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,EPATM,PESTM
      REAL*8 DATPL,DATMAT,DATMAR
C
      COMMON /EVAPIN/ ELE2, DATA(5,20), DATAN(5,20),
     1                RUFF,SRES,DELGAM(121),SVPRES(121),VPRE2,VPDEF,
     2      ATRES,POEVAP,TOTVAP
C
      COMMON /CONST/ CON(50),IOPT(50),KDUMM,NZPREV, NZERO
C
      COMMON /ADDATA/ C(27,20), S(27,20), KNT, SSS(27,20)
     1      ,DC(27), VEL(27), THETJ(27), B(27),KDES(27,20),CMAXUM(27,20),
     2      THETX,XMAX, H, KTIME,II, A, DENOM,DENAM,INDEX(20),INDEX1(20),
     3      ANT, AX, IISAVE, IGOR, NVAL(20),DESKRO, XPONT,KLEW1(20),DVST,
     4      THETAT, SUMC(27), SUMS(27),CUMAD, CUMDS,PTOT(20) ,C1(27,20)
     5      , VPAST(27,20),KSW(20),INTGER ,NOSTOP(20),ADRX,DSRX
     6     ,TOTAD,TOTDS,ZROC(27,20),CCL(27),SSL(27),TOT(27)
C
      DIMENSION SUMTH(20)
      NAMELIST/BUG1/C,S,THETN
      NAMELIST/BUG2/EXX,RDT,ADJLL,CBAR,DSRO,SBAR,ADRO,ES,EC
     1  ,CUMAD,CUMDS ,CUMRO
     2  ,XUMRO,TEMPAD,XADJLI,TEMPDS
C
      PTOTV = TOTVAP
      PRO = CUMRO
      PSED = ADJLI(21)
      WATROT = CUMRO
      ADRX = 0.
      DSRX = 0.
      RDT = 0.
      ADJLL = 0.
C   MOVE PESTICIDE
C  MOVE SEDIMENT & RUNOFF
      DO 10 I=1,NZN
      ADJLI(I) = 0.
      THETA(1,I) = 0.
      SUMTH(I) = THETN(1,I)
      IZN = SUB(8,I)
```

SCRAM Program Listing (Continued)

```
      DO 10 J=2,IZN
      THETA(J,I) = THETN(J,I)
      SUMTH(I) = SUMTH(I) + THETN(J,I)
 10   CONTINUE
 9    IF (IDRY .EQ. 0) GO TO 35
C  EMO= MONTHS SINCE PEST. DATE
      EMO= (TOLO-PESTM)/ (60.*60.*24.*30.)
      EXX= EXP(-EMO)
      DO 25 I=1,NZN
C  CHECK FOR MAX RUNOFF RATE
      ROMAX = SUB(10,I)*DT*THETN(1,I)
      IF (THETN(1,I) .LE. ROMAX) GO TO 12
      THETA(1,I) = THETA(1,I) + THETN(1,I) - ROMAX
      THETN(1,I) = RUMAX
 12   DO 20 J=1,4
      IF (INF(J,I) .LE. 0) GO TO 20
      IF (INF(J,I) .LE. 20) GO TO 15
C  ACCUMULATE RUNOFF AND
C  CHANGE TO LITERS
      CUMRO = CUMRO + THETN(1,I)*RNF(J,I)*SUB(2,I)*SUB(9,I)/1000.
      XUMRO = XUMRU + THETN(1,I)*RNF(J,I)*SUB(2,I)*SUB(9,I)/1000.
      RDT = RDT + THETN(1,I)*RNF(J,I)*SUB(2,I)*SUB(9,I)/1000.
      ADJLL = ADJLL + ADJLO(I) * RNF(J,I)
      XADJLI= XADJLI+ ADJLO(I) * RNF(J,I)
      GO TO 18
 15   THETA(1,INF(J,I)) = THETA(1,INF(J,I)) + THETN(1,I)*RNF(J,I)
     1 *SUB(2,I)*SUB(9,I)/(SUB(2,INF(J,I))*SUB(9,INF(J,I)))
 18   ADJLI(INF(J,I)) = ADJLI(INF(J,I)) + ADJLO(I)*RNF(J,I)
 20   CONTINUE
   25 CONTINUE
C               CALCULATE TOTAL C AND S VALUES FOR EACH LAYER
      DO 42 I=1,KNT
      CCL(I) = 0.
      SSL(I) = 0.
      DO 41 J=1,NZN
      CCL(I) = CCL(I) + C(I,J)*THETN(I+1,J)
   41 SSL(I) = SSL(I) + S(I,J)*SUB(6,J)
C
C               COMPUTE AVERAGES
      CCL(I) = CCL(I) / NZN
      SSL(I) = SSL(I) / NZN
   42 TOT(I) = CCL(I) + SSL(I)
C
C
C  CALCULATE AMT. OF PESTICIDE IN RUNOFF AND  SEDIMENT( MICROGRAMS)
C
      CBAR = (CCL(1) + CCL(2))/2.
      DSRO=RDT*2.2E-4 *CBAR*EXX
      SBAR = (SSL(1) + SSL(2))/2.
      ADRO=ADJLL*0.08 * SBAR *EXX
      ADRX = ADRX + ADRO
      DSRX = DSRX + DSRO
      CUMAD = CUMAD + ADRO
      CUMDS = CUMDS + DSRO
```

SCRAM Program Listing (Continued)

```
C
C
C   MAKE ADJUSTMENTS TO FIRST LAYER OF C  AND S
C               CALCULATE TOTAL AREA OF WATERSHED   SQ.CM.
C
C   UNITS OF DSRO & ADRO --GRAMS
C   CHANGE TO MICROGRAMS
      DDDD=DSRO*1.E+6
      AAAA=ADRO
      TAREA = 0.
      DO 40 I=1,NZN
   40 TAREA = TAREA + SUB(2,I)
C               CALCULATE PESTICIDE BALANCE
      DO 43 I=1,NZN
C
C               FRACTION OF PESTICIDE LOSS FROM SPECIFIC WATERSHED
C               BY FRACTION OF AREA
      AREA2 = SUB(2,I) / TAREA
C
C               TOTAL GRAMS OF PESTICIDE DISSOLVED IN LAYERS 1 AND 2
      ETOT = (C(1,I)*THETN(2,I)+C(2,I)*THETN(3,I))
      STOT = (S(1,I)+S(2,I))*SUB(6,I)
C
C               REMOVE PESTICIDE FROM TOP 2 LAYERS
      IF(ETOT.EQ.0.)  GO TO 83
      C(1,I) = (C(1,I)*THETN(2,I)-C(1,I)*THETN(2,I)/ETOT*DDDD/TAREA)
     1/THETN(2,I)
      C(2,I) = (C(2,I)*THETN(3,I)-(C(2,I)*THETN(3,I)/ETOT*DDDD/TAREA))
     1/THETN(3,I)
   83 IF(STOT.EQ.0.) GO TO 43
      S(1,I) = (S(1,I)*SUB(6,I)-AAAA/TAREA*S(1,I)/STOT)/SUB(6,I)
      S(2,I) = (S(2,I)*SUB(6,I)-(AAAA/TAREA*S(2,I)/STOT))/SUB(6,I)
   43 CONTINUE
C
C   BALANCE WATER
C
   35 DO 24 I=1,NZN
C   WATER IN = SUM(THETA(0) + RAINR*DT)
      RAIN = RAINR(I)*DT*SUB(2,I)/1000.
      SUMIN = SUMIN + RAIN
      SUMRN = SUMRN + RAIN
C   WATER OUT = SUM(THETA + RUNOFF)
 24   WATROT = WATROT + SUMTH(I)*SUB(2,I)*SUB(9,I)/1000.
 99   CONTINUE
C   CALCULATE RUNOFF AND SEDIMENT RATES
      ROR = (CUMRO-PRO)/DT
      SEDRAT = (ADJLI(21)-PSED)/DT
C   INCLUDE EVAPOTRANSPIRATION AND INFILTRATION LOSS TO WATER OUT
      WATROT = WATROT + CUMFLT + PTOTV
      IF (IOPT(6) .NE. 0)
     *CALL DATOUT (TNEW,D,0)
      NZPREV=NZERO
      DO 205 I=1,NZN
      RR = THETN(1,I)*SUB(9,I)/DT
```

SCRAM Program Listing (Continued)

```
      ELF = ADJLD(I) / (SUB(5,I)*DT)
      IF((RN.EQ.0.).AND. (ELF.EQ.0. )) GO TO 205
      NZERO=1
      GO TO 208
  205 CONTINUE
      NZERO=0
      IF(NZPREV.NE. 1)  GO TO 208
      CALL OUTPUT(5)
  208 CONTINUE
      RETURN
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE CONTAM(NZ,IDRY)
C
C   SUBROUTINE TO PREDICT THE SIMULTANEOUS CONCENTRATION OF PESTICIDE
C    ADSORBED AND IN SOLUTION WITHIN THE SOIL MATRIX.
C
C   C=SOLUTE CONCENTRATION OF SOLUTE
C   S=ADSORBED VALUES
C   NEXP=THE CONSTANT EXPONENT ON THE TERM C**N,NEXP=N
C   AB= THE CONSTANT IN THE EXPONENT ON THE TERM C**(1/AB)
C       USED FOR DESORPTION
C   VEL= VELOCITY
C   RHO= BULK DENSITY OF SOIL
C   K= THE CONSTANT K
C   D= DIFFUSION COEFFICIENT
C   DVS= CONSTANT DIFFUSION COEFFICIENT FOR VAPOR PHASE OF C,USED FOR
C    INFILTRATION AND REDISTRIBUTION TO CALCULATE SURFACE FLUX OF CHEMICA
C   CO= MAGNITUDE OF INPUT PULSE
C   PULSE= THE DISTANCE IN THE SOIL OF THE LEADING EDGE OF AN INITIALLY
C      DISTRIBUTED CHEMICAL
C
      COMMON/CONST/CON(50),IOPT(50)
C
      COMMON /SEDATA/SUB(10,20)
C
      REAL K,KTIME,NEXP,KRHO,KDES,KOND,INFILT
C     DIMENSION VPAST(802),CLORID(802),TTIMER(200),DELXMT(200)
C
      COMMON /TIMES/ TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,
     1     EPATM, PRINT(3), PROGDT(3), PESTM
      REAL*8 TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,EPATM,PESTM
      COMMON /ADDATA/ C(27,20), S(27,20), KNT, SSS(27,20)
     1     ,DC(27), VEL(27), THETJ(27), B(27),KDES(27,20),CMAXUM(27,20),
     2     THETX,XMAX, H, KTIME,II, A, DENOM,DENAM,INDEX(20),INDEX1(20),
     3     ANT, AX, IISAVE, IGOR, NVAL(20),DESKRO, XPONT,KLEW1(20),DVST,
     4     THETAT, SUMC(27), SUMS(27),CUMAD, CUMDS,PTOT(20) ,C1(27,20)
     5     , VPAST(27,20),KSM(20),INTGER ,NOSTOP(20),ADRX,DSRX
     6     ,TOTAD,TOTDS,ZROC(27,20)
C
      COMMON /WATERD/ NZN, RAINR(20),  THETA(27,20),THETN(27,20),CUMRD
     1     ,CUMFLT,DHTAB(50,4,10),NUMDH(10),RINF(20),CIT(20),VELC(27,20)
     2     ,Q(27,20),SUMRN,WATROT,SUMIN,ROR
C
      EQUIVALENCE           (CON(10),K),(CON(11),RHO),(CON(12),T),
     1          (CON(13),NEXP),(CON(14),AB),(CON(15),CO),(CON(16),PULSE)
     2     ,(CON(17),DVS),(CON(18),D),(IOPT(8),NOREAD)
      NAMELIST /DEBUG/NVAL,PTOT,II,TOTC1,TOTC,NOREAD
      NAMELIST /SEE/C,A,B
C
      IF(INTGER.NE.0) GO TO 650
      INTGER=1
      DESKRO= K   /AB
      IF(IOPT(1).NE.0)  GO TO 7711
      DO 1150 J=1,27
      DO 1150 I=1,20
```

SCRAM Program Listing (Continued)

```
 1150 KDES(J,I)= DESKRO
 7711 CONTINUE
      JJ = 1
      JXT = 2
      DAY = 1.
      COND = .366
      INT = 1
      INFILT=0
C
      NUCLOR=0
C
C     WRITE(6,10) N,NUMBER,NOREAD,NUCLOR
C
C
C
C     WRITE(6,20) D,K,RHO,T,NEXP,AB,CO,PULSE,DVS
C
      DENOM=0
      DENAM=0
      AX= NEXP-1.
      ANT = 1./AB-1.
      XPONT= NEXP-1./AB
      D= D *DAY
      DVS=DVS*DAY
      DABSD= ABS(D)
      DXP= ABS(XPONT)
      IF(DXP .LT. 1.E-60) XPONT= 1.E-60
      IF((ANT .LT. 1.E-60)  .AND. (ANT .GT. -1.E-60)) ANT= 1.E-60
      IF((AX .LT. 1.E-60) .AND. (AX .GT. -1.E-60)) AX = 1.E-60
  650 CONTINUE
      KTIME=DT/3600.
C     II IS NUMBER OF LAYERS + 3
C
      II = SUB(8,NZ)-2
      IISAVE = II
      IIP1=II+1
      DO 115 I=1,IIP1
      THETJ(I) = THETN(I+1,NZ)
  115 VEL(I) = VELC(I,NZ)
      RHO = SUB(6,NZ)
      H = SUB(9,NZ)
      ADKH= D/H/H
      XMAX = H*SUB(8,NZ)
      THETJ(II+1) = THETJ(II)
      ARHO = K    *NEXP
      THETX= THETJ(II)
C                   CHECK EVAPOTRANSPIRATION ONLY FLAG
C                   IF YES, GO TO ROUTINE TO CALCULATE NEW CONCENTRATIONS
C                   DEPENDING ON THE NEW THETA VALUES CALCULATED
      IF (IDRY.EQ.0) GO TO 6000
      IF (NOREAD) 590,590,600
600   CONTINUE
C
C     WRITE(6,580) (C(J,NZ),J=1,KUICK)
```

SCRAM Program Listing (Continued)

```
C
C
C     IF(NOCLOR .EQ. 1) READ(5,580) (CLORID(J),J=1,KUICK)
C
C
C     WRITE(6,580) (S(J,NZ),J=1,KUICK)
C
C
      IF(KSW(NZ).GT.0) GO TO 1140
      KSW(NZ)=1
      KQUIT = 0
      DO 1210 I=1,II
      J= II - I + 1
      IF(KQUIT) 1220,1220,1230
 1220 THEK= S(J,NZ)  /(C(J,NZ) **NEXP)
      IF((THEK .GT. 1.015*K) .OR. (THEK .LT. .985*K)) KQUIT=J
      IF(KQUIT .EQ.0) GO TO 1210
 1230 CMAXUM(J,NZ) = CO
      KDES(J,NZ)= S(J,NZ)/AB/(C(J,NZ)**(1./AB))
 1210 CONTINUE
      IF(KQUIT .GT. 1) INDEX(NZ)=KQUIT
      INDEX1(NZ)= INDEX(NZ)+1
      KLEW1(NZ)= INDEX1(NZ)
 1200 TIME= 0
      GO TO 1140
  590 CONTINUE
      IF(CMAXUM(1,NZ).EQ.0) CMAXUM(1,NZ)= CO
      TIME= 0
C  CALCULATE VELOCITY
  420 CONTINUE
 1130 DO 390 J=2,II
      XTHET= (THETJ(J+1)   -THETJ(J-1)   )/2./H
      DERIV= (VEL(J)   -VPAST(J,NZ))/KTIME/THETJ(J)
      VPAST(J,NZ)= VEL(J)
      VEL(J) = VEL(J)/THETJ(J)
      GG= (-VEL(J)   *VEL(J)   /THETJ(J)   *XTHET-DERIV)*KTIME/2.
      ZZ= VEL(J)   -D*XTHET/THETJ(J)
      B(J)= (ZZ-GG)*KTIME/H
  390 UC(J)= RHO/THETJ(J)
      VPAST(1,NZ)= VEL(1)
      VEL(1) = VEL(1)/THETJ(1)
      UC(1)= RHO/THETJ(1)
      A= ADKH*KTIME
      VAVGR= (VEL(1)   +VEL(2)   )*.5
      DENOM= (D+.08*VAVGR)/(D+(.08+H)*VAVGR)
      DENAM= (DABSD+.08*VEL(II)   )/(DABSD+(H+.08)*VEL(II)   )
   70 C(1,NZ)= CO
      C1(1,NZ) = CO
C
C     CLORID(1)= CO
C
  460 DVST=  DVS*THETJ(1)
C         CALCULATE TOTAL UG OF PESTICIDE IN ZONE
      TOTC1 = 0.
```

SCRAM Program Listing (Continued)

```
      DO 470 I=1,II
  470 TOTC1 = TOTC1 + C(I,NZ) * THETA(I+1,NZ) + S(I,NZ) * SUB(6,NZ)
      DO 21 I=1,II
   21 C(I,NZ)= C1(I,NZ)
      CALL RUNGE(II,KRHO,NZ)
      IF(NOREAD.EQ.0) C(1,NZ)= CO
      DO 22 I=1,II
   22 C1(I,NZ) = C(I,NZ)
      TIME= TIME + KTIME
      NNV=NVAL(NZ)
      GO TO (480,160), NNV
  480 IF( PTOT(NZ) .GE.T) GO TO 60
      GO TO 160
 1140 DC(JJ)= RHO/THETJ(JJ)
C   CALCULATE VELOCITY
      DO 396 J=JXT,II
      XTHET= (THETJ(J+1)     - THETJ(J-1)    )/2./H
      DERIV= (VEL(J)    -VPAST(J,NZ))/KTIME/THETJ(J)
      VPAST(J,NZ)= VEL(J)
      VEL(J) = VEL(J)/THETJ(J)
      GG=  (-VEL(J)    *VEL(J)    /THETJ(J)    *XTHET-DERIV)*KTIME/2.
      ZZ= VEL(J)    -D*XTHET/THETJ(J)
      B(J)= (ZZ-GG)*KTIME/H
  396 DC(J)= RHO/THETJ(J)
      VPAST(1,NZ)= VEL(1)
      VEL(JJ) = VEL(JJ)/THETJ(JJ)
      A= ADKH*KTIME
      VAVGR= (VEL(1)    +VEL(2)    )*.5
      DENOM=(D+.08*VAVGR)/(D+(.08+H)*VAVGR)
      DENAM= (DABSD+.08*VEL(II)    )/(DABSD+(H+.08)*VEL(II))
      GO TO 460
C
C
   60 INDEX(NZ)= 2
      INDEX1(NZ)=2
      NVAL(NZ)=2
C
C
  160 CONTINUE
C
C     WRITE(6,30) A1,A4,K,BTIME,THETAT,RHO,A2,CO,AB,NEXP
C
C
C     WRITE(6,5000) D, A4
C
C
C
      KNT=0
      DO 171 J=1,IISAVE
      IF(IDRY.EQ.0) GO TO 363
      IF(J .GE. INDEX(NZ)) GO TO 363
C   CALCULATE ADSORBED VALUES
      S(J,NZ)= KDES(J,NZ)*AB*C(J,NZ)**(1./AB)
      GO TO 171
```

SCRAM Program Listing (Continued)

```
  363 S(J,NZ)= K*C(J,NZ)**NEXP
  171 CONTINUE
      DO 170 J=1,IISAVE,INT
 360  SSS(J,NZ) = S(J,NZ)
C
C     IF(NOCLOR) 1180,1180,1190
C1190 WRITE(6,210) TIMM,X,PVOL,C(J,NZ),SS,VELJJJ,THETA(J,NZ),HJ(J),
C    1               CLORID(J)
C
C     GO TO 170
C
C  LEAVE IN FOR NOW
C1180 WRITE(6,210) TIMM,X,PVOL,C(J,NZ),SS,VELJJJ,THETJ(J)
C
      KNT=KNT+1
  170 CONTINUE
      IF(IDRY.EQ.0) GO TO 175
C  DO AVERAGE ON C
      IIM1= II-1
      DO 5 I=1,IIM1
      S(I,NZ) = (S(I,NZ) + S(I+1,NZ)) * .5
    5 C(I,NZ) = (C1(I,NZ) + C1(I+1,NZ)) * 0.5
      C(II,NZ) = C1(II,NZ) * 0.5
      S(II,NZ) = S(II,NZ) * .5
      IF (NOREAD.EQ.0) GO TO 175
C           CALCULATE TOTAL UG OF PESTICIDE AFTER RUNGE
      LL = 2
 5005 CONTINUE
      L = LL - 1
      IF(ZROC(L,NZ).NE.0.) C(L,NZ) = 0.
      IF(C(L,NZ).GT.0.) GO TO 5004
      C1(L,NZ) = 0.
      S(L,NZ) = 0.
      LL = LL + 1
      IF(LL.GT.II) GO TO 220
      GO TO  5005
 5004 CONTINUE
      TOTC = 0.
      DO 25 I=LL,II
   25 TOTC= TOTC +  C(I,NZ)*THETN(I+1,NZ) + S(I,NZ) * SUB(6,NZ)
      TOTC1 = TOTC1 - TOTC
      IF(TOTC1.GT.0.) GO TO 5003
      TOTC1 = TOTC1 + TOTC
      L = LL-1
      C(L,NZ) = 0.
      C1(L,NZ) = 0.
      S(L,NZ) = 0.
      ZROC(L,NZ) = 1.
      LL = LL + 1
      GO TO 5004
 5003 CONTINUE
C     CALCULATE NEW C1(1,NZ)
      ID = 2
      L = LL - 1
```

SCRAM Program Listing (Continued)

```
      COLD = C(L,NZ)
      CALL NEWRAP(L,NZ,ID,TOTC1,COLD)
      C1(L,NZ) = 2. * C(L,NZ) - C1(LL,NZ)
      S(L,NZ)= ADES(L,NZ)*AB*C(L,NZ)**(1./AB)
   24 CONTINUE
  175 CONTINUE
      PTOT(NZ) = 0.
      DO 230 I=1,II
  230 PTOT(NZ) = PTOT(NZ) + C(I,NZ) * THETN(I+1,NZ) + S(I,NZ) *SUB(6,NZ)
C 175 CALL SIMPSN (SUM,IISAVE,NZ)
C     WRITE(6,82) SUMC(NZ),SUMS(NZ),SUM
C
C     IF(NOCLUR.EQ.1) WRITE(6,91) SUMCL
C
 220  RETURN
C                   DURING EVAPGRATION ONLY, CALCULATE NEW VALUES OF C
C                   USING NEW THETA VALUES
6000  CONTINUE
C
C  CALCULATE A  NEW VALUE OF C  BY THE NEWTON- RAPHSON TECHNIQUE
      ID = 1
      DO 6010 L=1,II
      IF(C(L,NZ) .EQ. 0.) GO TO 6010
      TOTC1 = C(L,NZ) * THETJ(L)   + S(L,NZ) * SUB(6,NZ)
      CALL NEWRAP(L,NZ,ID,TOTC1,COLD)
 6010 CONTINUE
C
C  SET INDEX FLAG FOR ADSORPTION VS DESORPTION... WANT ONLY ADSORPTION
C
C
C  GO TO ROUTINE THAT CALCULATES SORBED CONC. FROM SOLUTION CONC.
C
      GO TO 160
   10 FORMAT(6I5)
   20 FORMAT(5F15.5)
   30 FORMAT (19X,      'VEL=',F10.3,5X,'D=',F10.3,5X,'K=',F10.3,5X,
     *'KTIME=',E10.3,5X,'THETA=',F10.3,/19X,'RHO=',F10.3,5X,'T=',F10.3,
     *5X,'CO=',F9.3,8X,'AB=',F10.3,6X,'NEXP=',F10.3,
     *///,T9 ,'TIME',T2[illegible],'X',T35,'PORE VOLUME',T54,'C      S=K*C**(N OR
     *1/AB)',T82,'VELOCITY',T99,'THETA',T109,'PRESSURE, H',' CLORIDE:K=
     *0')
   82 FORMAT(1X,'THE TOTAL AMOUNT OF CONCENTRATION, C, PRESENT IS, C*THE
     *TA=',T64,F11.4,/,1X,'THE TOTAL AMOUNT OF CONCENTRATION, S, PRESENT
     * IS, S*RHO=',  T64,F11.3,/,'+',T64,'            ',/,1X, 'THE SUM OF
     * S AND C IS, RHO*S + C*THETA=',  T64,F11.4)
C
C  91 FORMAT(1X,/,1X,'THE AMOUNT OF CLORIDE CONCENTRATION PRESENT IS CLO
C    *RIDE*THETA=',T64,F11.4)
C
  104 FORMAT(20A4)
  109 FORMAT(1X,T23,84('*'),/,1X,T23,'*',T25,20A4,1X,'*',/,1X,T23,84('*'
     *),/)
  210 FORMAT( 3X,2(F11.5,4X),F11.5,2E15.5,4X,2(F11.5,4X),F11.3,E12.5)
  306 FORMAT(5X,/,5X,'SINCE C/CO,AFTER 100 INTERATIONS, IS .GT. 0 AND .L
```

SCRAM Program Listing (Continued)

```
     *I. 1.0. THE CALCULATIONS WILL PROCEED USING THIS VALUE.',/)        00007740
 380 FORMAT(1X,/,5X,'FOR THE PARAMETERS: K=',F12.4,', NEXP=',F12.4,', C00007750
     *J=',F12.4,', RHO=',F12.4,', THETA=',F12.4,//,5X,'AND FOR AN INITIA00007760
     *LLY DISTRIBUTED PULSE, CONVERGENCE DID NOT OCCUR ON THE ITERATIVE'00007770
     *,/,5X,'CALCULATIONS OF THE INITIAL C/CO AND S/CO VALUES. AFTER 10000007780
     * ITERATIONS THE VALUE OF C/CO= ',E14.7,/)                          00007790
 391 FORMAT(5X,/,5X,'THE CALCULATION OF C/CO IS OUTSIDE THE ALLOWED RAN00007800
     *GE.',/,5X,'THEREFORE, YOU MUST READ IN THE VALUES OF C/CO AND S/CO00007810
     * ON CARDS. THIS CAN BE DONE BY SETTING THE VALUE OF NOREAD=1',/)  00007820
 500 FORMAT(8F10.0)                                                     00007830
 990 FORMAT(1X,/,1X,'FOR THE ABOVE, INFILTRATION RATE= ',F12.7,',  ### 00007840
     * CUMULATIVE INFILTRATION= ',F12.7,' INFILTRATION DELT, TINCER=',F100007850
     *4.7,/)                                                            00007860
 999 FORMAT(1H1)                                                        00007870
5000 FORMAT(/// '  D.A4' , 2F10.3 ///)                                  00007880
     END                                                                00007890
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE DATEIN(DI,DPSEC)
C
C     DI(1) = YEAR                                      (INPUT)
C     DI(2) = MONTH                                     (INPUT)
C     DI(3) = DAY                                       (INPUT)
C     DI(5) = MINUTE                                    (INPUT)
C     DI(4) = HOUR                                      (INPUT)
C     DI(6) = SECONDS                                   (INPUT)
C     DPSEC = DOUBLE PRECISION SECONDS FROM JAN 0, 1900    (OUTPUT)
C
      DOUBLE PRECISION  DPSEC,Y
      DIMENSION I(5)
      DIMENSION          J(11),DI(6)
      DATA               J/31,59,90,120,151,181,212,243,273,304,334/
C
      DO 1 K=1,6
      IF (DI(K) .GT. 0.) GO TO 3
 1    CONTINUE
    2 WRITE(6,1000) DI
 1000 FORMAT(1X, 'S.R. DATEIN , DI= ', 6E12.5)
      CALL ERROR( 1)
 3    I(3) = DI(3)
      I(2) = DI(4)
      I(5) = DI(5)
      Y=60*(I(5)+60*I(2))
      DPSEC = Y + DI(6)
   10 I(3)=I(3)-1
      I(4) = AMOD(DI(1),100.)
      I(1) = INT(DI(2)) - 1
      IF (I(1) .GT. 11) GO TO 2
      IF (I(1)) 2,13,12
 12   JJ = I(1)
      I(3)=I(3)+J(JJ)
   13 I(5)=I(4)-4*(I(4)/4)
      IF(I(1)/2+I(5).LE.0) I(3)=I(3)-1
      Y = I(3) + (4+1461*I(4))/4
      DPSEC=DPSEC+86400.D0*Y
      RETURN
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE DATINT
C
C  READ IN RAIN AND EPA CARDS UP TO START TIME
C  AND PLACE RAIN RATE, EPA DATA, AND TIMES IN COMMON
C
      COMMON /WATERD/ NZN, RAINR(20),  THETA(27,20),THETN(27,20),CUMRO
     1      ,CUMFLT,DMTAB(50,4,10),NUMDH(10),RINF(20),CIT(20),VELC(27,20)
     2      ,Q(27,20),SUMRN,WATROT,SUMIN,ROR,RDT ,XUMRU
C
      COMMON /EVAPIN/ ELE2,DATA(5,20),DATAN(5,20)
C
      COMMON /TIMES/ TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,
     1      EPATM, PRINT(3), PROGDT(3)
      REAL*8 TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,EPATM
C
      COMMON /CONST/ CON(50)
      EQUIVALENCE (CON(6),THRSH1),(CON(7),THRSH2)
      COMMON /SEDATA/ SUB(10,20),ADJLI(21)
      COMMON /ADDATA/ C(27,20), S(27,20), KNT, SSS(27,20)
     1      ,DC(27), VEL(27), THETJ(27), B(27),KDES(27,20),CMAXUM(27,20),
     2      THETX,XMAX, H, KTIME,II, A, DENOM,DENAM,INDEX(20),INDEX1(20),
     3      ANT, AX, IISAVE, IGOR, NVAL(20),DESKRO, XPONT,KLEW1(20),DVST,
     4      THETAT, SUMC(27), SUMS(27),CUMAD, CUMDS,PTOT(20) ,C1(27,20)
C
      DIMENSION RAIN(20)
C
      REAL*8 SEC
C  RAIN DATA
      DO 22 I=1,NZN
   22 RAINR(I)=0.
 10   READ (11,END=20) SEC,(RAIN(I),I=1,NZN)
      IF (SEC .GT. TSTRT) GO TO 25
      DO 31 I=1,NZN
   31 RAINR(I)= RAIN(I )
      GO TO 10
 20   SEC = 1.D30
 25   TRAIN = SEC
C  EPA DATA
      DO 28 J=1,5
      DO 28 I=1,NZN
   28 DATA(J,I)=0.
 30   READ (12,END=40) SEC, ((DATAN(J,I ),J=1,5),I=1,NZN)
      IF (SEC .GT. TSTRT) GO TO 45
      DO 35 J=1,5
      DO 35 I=1,NZN
   35 DATA(J,I)= DATAN(J,I)
      GO TO 30
 40   SEC = 1.D30
 45   EPATM = SEC
C  CORRECT SOLAR RADIATION FOR LATITUDE AND MONTH
      DO 32 I=1,NZN
   32 DATA(3,I)= SOLAR(DATA(3,I),TSTRT )
      GO TO 56
      ENTRY DATIN
```

SCRAM Program Listing (Continued)

```
C  ENTRY TO READ NEXT RAINFALL CARD
      DO 33 I=1,NZN
   33 RAINR(I)=RAIN(I)
      READ (11,END=50) SEC, (RAIN (I),I=1,NZN)
      GO TO 55
 50   SEC = 1.030
 55   TRAIN = SEC
C  CALCULATE NEW VALUE OF PRINT INTERVAL
 56   PIN = PRINT(3)
      DO 57 I=1,NZN
      IF (THETA(2,I) .GT. THRSH2) PIN = PRINT(2)
      IF (RAINR(I) .GT. THRSH1) PIN = PRINT(1)
 57   CONTINUE
      RETURN
      ENTRY DATEPA
C  ENTRY TO READ NEXT EPA DATA CARD
      DO 60 I=1,NZN
      DO 60 J=1,5
 60   DATA(J,I)= DATAN(J,I)
      READ (12,END=70) SEC,((DATAN(J,I),J=1,5),I=1,NZN)
      GO TO 75
 70   SEC = 1.030
 75   EPATM = SEC
C   CORRECT SOLAR RADIATION
      DO 37 I=1,NZN
   37 DATA(3,I)= SOLAR(DATA(3,I),THEW)
      RETURN
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE DATOUT(DPSEC,D,K)
C
      COMMON /CONST/ CON(53),IOPT(50)
C
C     DPSEC = DOUBLE PRECISION SECONDS FROM 1900 (INPUT)
C     D(1) = YR MO.       FORMAT OF DATINP          (OUTPUT)
C     D(2) = DAY HR MIN.  FORMAT OF DATINP          (OUTPUT)
C     D(3) = SEC.         FORMAT OF DATINP          (OUTPUT)
C     K= 0 GIVES CALENDAR DATE FORMAT OUTPUT
C
      DOUBLE PRECISION DPSEC,TDUM,Y4,Y5,Y6,Y7,Y8
      DIMENSION          C(12), D(3), IY(4)
C
C
C
      DATA C/  3HJAN, 3HFEB, 3HMAR, 3HAPR, 3HMAY, 3HJUN
     &,        3HJUL, 3HAUG, 3HSEP, 3HOCT, 3HNOV, 3HDEC /
C
  601 FORMAT(1H ,A3,I3,1H,,I5,1H,,I3,5H HRS.,I3,5H MIN.,F9.5,4H SEC,5X,
     &                          39X,11HJULIAN DATE,7PD22.8)
C
      TDUM=DPSEC
      Y7 = IDINT(TDUM/86400.D0)
      IF(TDUM.LE.0.)CALL ERROR(2)
      TDUM=TDUM-Y7*86400.D0
      Y8=TDUM/86400.D0
      IY(1) = Y7
      IY(2) = IY(1)/365
   11 IY(3) = IY(1)-(1461*IY(2)+3)/4
      IF (IY(3).GE.0) GO TO 12
      IY(2) = IY(2)-1
      GO TO 11
   12 IY(4) = IY(2)  -4*(IY(2)/4)
      JJ = 0
      KD = 0
   13 CONTINUE
      MD = KD
      JJ = JJ+1
      GO TO (14,16,14,15,14,15,14,14,15,14,15,14) ,JJ
   14 KD = KD+31
      GO TO 17
   15 KD = KD+30
      GO TO 17
   16 IF (IY(4).EQ.0) KD=KD+1
      KD = KD+28
   17 IF (KD.LE.IY(3)) GO TO 13
   20 IY(1) = IY(3)-MD+1
      Y1 = C(JJ)
      D(1)=JJ+100*IY(2)
      IY(2) = IY(2)+1900
C
   30 CONTINUE
      Y4 = IDINT(TDUM/3600.D0)
      TDUM = TDUM - Y4*3600.D0
```

SCRAM Program Listing (Continued)

```
      Y5 = IDINT(TDUM/60.D0)
      TDUM = TDUM - Y5*60.D0
      IV(3) = Y4
      IV(4) = Y5
      Y6 = TDUM
      YY=IV(4)+100*(IV(3)+100*IV(1))
      D(2)=YY
      D(3) = Y4
C
   60 CONTINUE
      TDUM = Y7 + Y4 + 2415020.5D0
      IF (K.NE.0) GO TO 999
      WRITE (6,601) Y1,IV(1),IV(2),IV(3),IV(4),Y6,TDUM
  999 RETURN
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE DEGRAD
C
C  SUBROUTINE TO PREDICT AMT. OF PESTICIDE LOSS DUE TO CHEMICAL,
C   PHOTOCHEMICAL, AND MICROBIAL PROCESSES
C
C
      COMMON /CONST/ CON(50)
      EQUIVALENCE (CON(25),TMAX)
C
      COMMON /EVAPIN/ ELEZ,DATA(5,20)
C
      COMMON /TIMES/ TOLD,TNEW,DT
      REAL*8 TOLD,TNEW,DT
C
      COMMON /SEDATA/ SUB(10,20)
C
      COMMON /WATERQ/ NZN, RAINR(20),  THETA(27,20),THETN(27,20)
C
      COMMON /ADDATA/ C(27,20), S(27,20), KNT, SSS(27,20)
     1      ,DC(27), VEL(27), THETJ(27), B(27),KDES(27,20),CMAXUM(27,20),
     2      THETA,XMAX, N, KTIME,II, A, DENOM,DENAM,INDEX(20),INDEX1(20),
     3      AMT, AX, IISAVE, IGOR, NVAL(20),DESKRO, XPONT,ALBW1(20),DVST,
     4      THETAT, SUMC(27), SUMS(27),CUMAD, CUMDS,PTOT(20) ,C1(27,20)
     5      , VPAST(27,20),KSW(20),INTGER ,NOSTOP(20),ADRO,DGRO
C
      DELTM = DT/86400.
      DO 10 I=1,NZN
      TEMZ= DATA(2,I)
      TEM = TEMZ
      IF (TEM.GT.42.) RETURN
      IF(TEMZ .GT. 40.) TEM=10
      IF (TEMZ .GT. TMAX) TEM=15.
      ND = SUB(8,I)
      DO 10 J=2,ND
      R = RK(THETN(J,I),TEM)
C  PREDICT AMT. OF ADSORBED PESTICIDE
      S(J-1,I) = S(J-1,I) * EXP(R*DELTM)
C  PREDICT AMT. OF PESTICIDE IN SOLUTION
 10   CONTINUE
      C1(J-1,I) = C1(J-1,I)*EXP(R*DELTM)
      RETURN
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE ERAGR(N)
C
      WRITE(6,100) N
 100  FORMAT(' ERAGR, N=',I2)
      STOP
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE EVAP
C
C  SUBROUTINE TO CALCULATE POTENTIAL EVAPOTRANSPIRATION
C
      COMMON /EVAPIN/ ELE2,DATA(5,20), DATAN(5,20),          RUFF,
     1     SRES,DELGAM(121),SVPRES(121),VPRE2,VPDEF,ATRES,POEVAP
     2,TOTVAP
C
      COMMON /SEDATA/SUB(10,20),ADJLI(21),ADJLO(20),RNF(4,20),INF(4,20)
     1     ,SEDRAT,HECT,AK1(10),AK2(10),ST(10),ADJLL
C
      COMMON /WATERD/ NZN, RAINR(20),  THETA(27,20),THETN(27,20),CUMRO
     1     ,CUMFLT,DHTAB(50,4,10),NUMDH(10),RINF(20),CIT(20),QTOT(27,20)
     2     ,Q(27,20),SUMRN,WATROT,SUMIN,ROR,ROT ,XUMRO
C
      DIMENSION POTN(20)
C
C  ELE2=ELEVATION 2- HT AT WHICH MEASUREMENTS ARE MADE(CM)
C  WVL2=WIND VELOCITY (CM/SEC)
C  TEM2= AIR TEMPERATURE(DEG. C)
C  SRD= NET SOLAR RADIATION(CAL/CM**2 SEC)
C  AIRP= BAROMETRIC PRESSURE
C  RHUM= RELATIVE HUMIDITY(%)
C  RUFF=ROUGHNESS PARAMETER(CM)
C  SRES=SURFACE RESISTANCE(SEC/CM)
C  DELGAM=SATURATION VAPOR PRESSURE AS FUNC(DEG. C)
C  SVPRES=DELTA/GAMMA AS FUNC(DEG. C)
C  VPRE2= VAPOR PRESSURE
C  VPDEF=VAPOR PRESSURE DEFICIT
C  ATRES= ATMOSPHERIC RESISTANCE TO DIFFUSION(SEC/CM)
C  POEVAP=POTENTIAL EVAPOTRANSPORATION (CM/SEC)
C  TOTVAP=TOTAL WATER LOSS DUE TO EVAPOTRANSPIRATION (CM)
C
      COMMON /CONST/ CON(50)
      EQUIVALENCE (CON(1),MASDEN),(CON(2),LTHEAT),(CON(3),BOWEN),
     1     (CON(4),SHEATP),(CON(5),VONK)
      REAL MASDEN,LTHEAT
C
      COMMON /TIMES/ TOLD,TNEW,DT
      REAL*8 TOLD,TNEW,DT
C
      DIMENSION D(3)
C
      DO 100 K=1,NZN
      WVL2= DATA(1,K)
      TEM2= DATA(2,K)
      SRD= DATA(3,K)
      AIRP= DATA(4,K)
      RHUM= DATA(5,K)
C  ROUND AIRT TO NEAREST 0.5 FOR USE IN TABLE LOOK UPS
      I = 2.*TEM2 + 1.5
      IF (I.GT. 121 .OR. I .LT. 1) CALL ERROR(6)
      VPRESS= SVPRES(I)*1.333
      DGAM = DELGAM(I)
```

SCRAM Program Listing (Continued)

```
C
C  COMPUTE VARIABLES
C
      VPRE2 = AHUM*VPRESS
      PSYCON = BOWEN*AIRP
      VPDEF = VPRESS-VPRE2
C    NO SOLAR RADIATION AT NIGHT
      CALL DATOUT (TNEW,D,1)
      SRA = SRD
      IHR = AMOD(D(2),10000.)/100.
      IF (IHR .GT. 18 .OR. IHR .LT. 6) SRA = 0.
C
C  EVALUATE MAIN EQUATIONS
C
      ATRES = VONK**2/WVL2 * (ALOG(ELE2/RUFF))**2
      POEVAP = ((DGAM*SRA + MASDEN*SHEATP/(PSYCON*ATRES)*VPDEF)/
     &     (DGAM+1.+SRES/ATRES))/LTHEAT
      IF (POEVAP .LT. 0.) POEVAP=0.
C  REMOVE WATER DUE TO EVAPOTRANSPIRATION EVENLY FROM FIRST TWO LAYERS
 50   POTN(K) = POEVAP*DT
  100 CONTINUE
      DO 55 I=1,NZN
      IZN = SUB(8,I)-1
      ANT = POTN(I)/SUB(9,I)
      NS = SUB(1,I)
      DO 54 J=2,IZN
      DIF = THETN(J,I)-DHTAB(1,1,NS)
      IF (DIF .EQ. 0.) GO TO 54
 51   IF (ANT-DIF) 52,52,53
 52   THETN(J,I) = THETN(J,I) - ANT
      TOTVAP = TOTVAP + ANT*SUB(2,I)*SUB(9,I)/1000.
      GO TO 55
 53   THETN(J,I) = DHTAB(1,1,NS)
      TOTVAP = TOTVAP + DIF*SUB(2,I)*SUB(9,I)/1000.
      ANT = ANT-DIF
 54   CONTINUE
 55   CONTINUE
C
      RETURN
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE FILTR
C
C  SUBROUTINE TO CYCLE THROUGH THE ZONES, CALLING WATER FOR EACH.
C
      COMMON /WATERD/ NZN, RAINR(20),  THETA(27,20),THETN(27,20),CUMRO
     1     ,CUMFLT, DHTAB(50,4,10), NUMDH(10), RINF(20), CIT(20),
     2     VELC(27,20), Q(27,20)
C
      COMMON /TIMES/ TOLD,TNEW,DT
      REAL*8 TOLD, TNEW, DT
C
      COMMON /SEDATA/SUB(10,20),ADJLI(21),ADJLO(20),RNF(4,20),INF(4,20)
C
      COMMON /CONST/ CON(50)
      EQUIVALENCE (CON(6),THRSH1) , (CON(9),DTMIN)
C
      IC = 0
      NEWFLG = 0
      DT = TNEW-TOLD
      DO 5 I=1,NZN
      IF(RAINR(I).LE.THRSH1) GO TO 15
    5 CONTINUE
      DO 10 I=1,NZN
      DELTA = (0.039*SUB(9,I))/RAINR(I)
      IF (DELTA .GT. DT) GO TO 10
      DT = AMAX1(DTMIN,AINT(DELTA))
      IC = I
 10   CONTINUE
C  CALL WATER FOR CRITICAL ZONE FIRST
      IF (IC.NE. 0) CALL WATER(IC,NEWFLG)
C  THEN CALL WATER FOR THE REST OF THE ZONES
 15   DO 20 I=1,NZN
      IF (I.EQ.IC) GO TO 20
C  CHECK FOR PROFILE IDENTICAL TO REFERENCE
      IZN = SUB(8,I)
      DO 16 N=1,IZN
      IF (THETA(N,I) .NE. THETA(N,IC)) GO TO 18
 16   CONTINUE
C  THE SAME, COPY
      DO 17 N=1,IZN
      VELC(N,I) = VELC(N,IC)
      Q(N,I) = Q(N,IC)
 17   THETN(N,I) = THETN(N,IC)
      RINF(I) = RINF(IC)
      CIT(I) = CIT(IC)
      GO TO 20
 18   CALL WATER (I,NEWFLG)
 20   CONTINUE
      RETURN
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE INPUT
C
      COMMON /INPUTD/ STARTM(6),ENDTM(6),PLOTNM(5),PESTNM(5),
     1     PESDAT(11),CROPDT(10),ZONES(14,20) ,RUNOFF(2,4,20)
C
C
      COMMON /CONST/ CON(50),IOPT(50),KPEST
      COMMON /EVAPIN/ ELE2,DATA(5,20), DATAN(5,20),
     1                 RUFF,SRES,DELGAM(121),SVPRES(121),VPRE2,VPDEF,
     2     ATRES,PLEVAP
C
      COMMON /TIMES/ TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,
     1     EPATM, PRINT(3), PROGDT(3), PESTM ,DATPL,DATMAT,DATHAR
      REAL*8 TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,EPATM,PESTM
      REAL*8 DATPL,DATMAT,DATHAR
C
      COMMON /WATERD/ NZN, RAINR(20),  THETA(27,20),THETN(27,20),CUMRO
     1     ,CUMFLT,DHTAB(50,4,10),NUMDH(10),RINF(20),CIT(20),QTOT(27,20)
     2     ,Q(27,20),SUMRN,WATROT,SUMIN,ROR,RDT,XUMRO
C
      COMMON /SEDATA/SUB(10,20),ADJLI(21),ADJLO(20),RNF(4,20),INF(4,20)
     1    ,SEDWAT,HECT,AK1(10),AK2(10),ST(10),ADJLL
     2    ,XADJLI
C
      COMMON /ADDATA/ C(27,20), S(27,20), KNT, SSS(27,20)
     1     ,DC(27), VEL(27), THETJ(27), B(27),KDES(27,20),CMAXUM(27,20),
     2     THETX,XMAX, H, KTIME,II, A, DENOM,DENAM,INDEX(20),INDEX1(20),
     3     ANT, AX, IISAVE, IGOR, NVAL(20),DESKRO, XPONT,KLEW1(20),DVST,
     4     THETAT, SUMC(27), SUMS(27),CUMAD, CUMDS,PTOT(20) ,C1(27,20)
     5     , VPAST(27,20),KSW(20),INTGER ,NOSTOP(20),ADRX,DSRX
     6     ,TOTAD,TOTDS
C
      COMMON /VOLTD/ ENG,ALFA,DV(27,20),DIST(27,20),IV1,PPB(27,20),
     1               DVS(27,20),P2
C
      DIMENSION CONV(5)
      DATA CONV /929.0304, 40468564., 30.48, 2.54, 62.4276/
      DIMENSION DHARAY(1520)
      DATA DHARAY /1520*0./
      DIMENSION D(3)
      REAL*8 NAM(10)
      DATA NAM/' LT CLAY',' SERL LM','3','4','5','6','7','8','9','10'/
C
      DIMENSION TEMP(6)
      DATA TEMP/6*0./
C
C
      NAMELIST /PEST1/ STARTM, ENDTM, PLOTNM, PESTNM, PESDAT, CROPDT,
     1     ZONES, RUNOFF, CON, IOPT, ELE2, RUFF, SRES, DELGAM, SVPRES,
     2     PRINT, PROGDT, THETA,AK1,AK2,ST,DHARAY,C,S
     3      , ENG, ALFA, DV, DIST
C
      READ(5,PEST1,END=999)
C  READ INPUT DATA FOR WARM START
```

SCRAM Program Listing (Continued)

```
      IF (IOPT(1) .EQ. 0) GO TO 5
      READ (14) ADJLI, CUMRO, KPEST, THETA, C,S, TSTRT,TOLD
     1   , CUMDS,CUMAD,VPAST,CMAXUM,NOSTOP,INDEX,INDEX1,KLEW1,KDES,KSW
     2   ,XUMRO,C1, TOTAD, TOTDS, XADJLI ,DT     ,CIT
     3   ,TNEW,SUMRN,SUMIN,TCTVAP,CUMFLT,NVAL ,THETN
      DTOLD= DT
 5    IF (IOPT(3).NE.0) WRITE(6,PESTI)
      CALL DATEIN (STARTM,TSTRT)
      CALL DATEIN (ENDTM,TSTOP)
      WRITE(6,1000) PLOTNM,PESTNM
 1000 FORMAT ('1', 50X 'BEGIN PESTICIDE SIMULATION'//      ' WATERSHED N
     1AME: ',5A4//    ' PESTICIDE NAME: ',5A4//    ' START DATE:')
      CALL DATOUT(TSTRT,D,0)
      WRITE(6,1001)
 1001 FORMAT('0',   'END DATE:')
      CALL DATOUT(TSTOP,D,0)
C  CALCULATE NUMBER OF ZONES
      DO 20 I=1,20
      IF (ZONES(1,I) .EQ. 0.) GO TO 25
 20   CONTINUE
      NZN = 20
      GO TO 30
 25   NZN = I-1
      IF (NZN .LE. 0) CALL ERRON(4)
 30   CONTINUE
C  INITIALIZE TIMES
      IF(IOPT(1).NE.0)  GO TO 100
      TNEW=TSTRT
      TOLD=TSTRT
  100 CONTINUE
      CALL DATEIN (PESDAT(6),PESTM)
C  CHANGE DATES TO DP SEC. DATPL IS DATE PLANTED
C                          DATHAR IS DATE HARVESTED
C                          DATMAT IS DATE OF MATURITY
      DO 81 J=1,3
   81 TEMP(J)= CROPDT(J+1)
      CALL DATEIN(TEMP,DATPL)
      DO 82 J=1,3
   82 TEMP(J)= CROPDT(J+4)
      CALL DATEIN(TEMP,DATHAR)
      DO 83 J=1,3
   83 TEMP(J)= CROPDT(J+7)
      CALL DATEIN(TEMP,DATMAT)
      WRITE(6,2000)
 2000 FORMAT('0PLANT DATE:   ')
      CALL DATOUT(DATPL,D,0)
      WRITE(6,2001)
 2001 FORMAT('0MATURITY DATE:   ')
      CALL DATOUT(DATMAT,D,0)
      WRITE(6,2002)
 2002 FORMAT('0HARVEST DATE:   ')
      CALL DATOUT( DATHAR,D,0)
C  SET UP SUB-PLOT DESCRIPTION
C
```

SCRAM Program Listing (Continued)

```
C  SUB(J,I) IS DEFINED AS FOLLOWS:
C   SUB(1,I)= SOIL TYPE
C   SUB(2,I)=AREA(CM**2)
C   SUB(3,I)=SLOPE(%)
C   SUB(4,I)=LENGTH(CM)
C   SUB(5,I)=WIDTH(CM)
C   SUB(6,I)=BULK DENSITY(GM/CM**3)
C   SUB(7,I)=NO. OF INCREMENTS FOR SED MODEL
C   SUB(8,I)=NO. OF LAYERS
C   SUB(9,I)=LAYER THICKNESS(CM)
C   (I=1,NZN WHERE NZN=NO. OF ZONES)
C
C
      WRITE(6,1002)
 1002 FORMAT('0',47X,'WATERSHED ZONE DEFINITION'// ' ZONE #',2X,
     1'SOIL TYPE', 8X,'AREA', 8X,'SLOPE',7X,'LENGTH',7X,'WIDTH',6X,
     2'DENSITY',5X,'SEDIMENT', 9X,'NO.', 8X,'LAYER'/  85X,'INCREMENTS',
     3 6X,'LAYERS', 5X, 'THICKNESS' / 25X,'CM**2', 7X,'PERCENT', 8X,
     4 'CM',11X,'CM', 6X, 'GM/CM**2',34X, 'CM' // )
      HECT = 0.
      DO 40 I=1,NZN
      DO 35 J=1,10
 35   SUB(J,I) = ZONES(J,I)
      SUB(3,I) = SUB(3,I)/100.
C  CHANGE UNITS IF NECESSARY
      IF (ZONES(11,I) .NE. 0.) SUB(2,I) = SUB(2,I)*CONV(INT(ZONES(11,I))
     1)
      IF (ZONES (12,I) .EQ. 0.) GO TO 36
      SUB(4,I) = SUB(4,I)*CONV(3)
      SUB(5,I) = SUB(5,I)*CONV(3)
 36   IF (ZONES(13,I) .EQ. 0.) GO TO 37
      J = ZONES(13,I) + 2
      SUB(9,I) = SUB(9,I)*CONV(J)
      SUB(10,I) = SUB(10,I)*CONV(J)
 37   IF (ZONES(14,I) .NE. 0.) SUB(6,I) = SUB(6,I) *CONV(5)
      HECT = HECT + SUB(2,I)/1.E8
      SUB(10,I) = SUB(10,I)*SUB(3,I)/SUB(4,I)
C  TO PRINT OUT VALUES OF  SUB(9,NZN)
      K = SUB(1,I)
 40   WRITE(6,1003) I,NAM(K),(SUB(J,I),J=2,9)
 1003 FORMAT(1X I2,3X A8,5X F13.0,2PF10.3,3X 0PF10.3,5(3XF10.3))
C  CHECK RUNOFF ARRAY AND SET UP RNF AND INF
C  RNF= % RUNOFF TO CORRESPONDING INF ZONE
C  INF= ZONE TO WHICH RUNOFF FROM ZONE I RUNS
      DO 45 I=1,NZN
      SUM = 0.
      DO 44 J=1,4
      IF (RUNOFF(2,J,I) .EQ. 0.) GO TO 44
      SUM = RUNOFF(2,J,I) + SUM
      IF (RUNOFF(1,J,I) .LE. 0.) CALL ERROR(7)
 44   CONTINUE
      IF (SUM .LE. 0.) CALL ERROR(7)
      DO 45 J=1,4
      INF(J,I) = RUNOFF(1,J,I)
```

SCRAM Program Listing (Continued)

```
      IF (INF(J,I).GT.21) CALL ERROR (7)                                00013340
 45   RNF(J,I) = RUNOFF(2,J,I)/SUM                                      00013350
      WRITE(6,1004)                                                     00013360
 1004 FORMAT('0', 50X,'RUNOFF DESCRIPTION'//' ZONE #',  4(9X,' TO ',11X,00013370
     1'$ ')//)                                                          00013380
C  TO PRINT OUT VALUES OF RUNOFF(2,4,NZN)                               00013390
      DO 50 I=1,NZN                                                     00013400
 50   WRITE (6,1005) I,(INF(J,I),RNF(J,I),J=1,4)                        00013410
 1005 FORMAT(1X I2,5X 4(I11,2PF15.3))                                   00013420
      IF(IOPT(1).NE.0) GO TO 501                                        00013430
C  INITIALIZE  THETN(J,I)                                               00013440
      DO 500 I=1,NZN                                                    00013450
      DO 500 J=1,27                                                     00013460
  500 THETN(J,I)= THETA(J,I)                                            00013470
  501 CONTINUE                                                          00013480
C                                                                       00013490
C  DE-INTERLEAVE DHARAY                                                 00013500
C                                                                       00013510
C     DHARAY(I) = SOIL TYPE                                             00013520
C     DHARAY(I+1) = NO. POINTS IN ARAY                                  00013530
C     DHARAY(I+2) ON = DATA                                             00013540
C                                                                       00013550
      I = 1                                                             00013560
 51   J = DHARAY(I)                                                     00013570
      IF (J .EQ. 0) GO TO 54                                            00013580
      K = DHARAY(I+1)                                                   00013590
      NUMDH(J) = K                                                      00013600
      I = I + 2                                                         00013610
      DO 53 L2 = 1,3                                                    00013620
      DO 53 L1 = 1,K                                                    00013630
      DHTAB(L1,L2,J) = DHARAY(I)                                        00013640
 53   I = I+1                                                           00013650
      GO TO 51                                                          00013660
 54   CONTINUE                                                          00013670
C                                                                       00013680
C TABLE DHTAB - COL 1 = THETA, COL2 = DIFFUSIVITY, COL 3 = PRESSURE     00013690
C        HEAD, COL 4 = PARTIAL SUM D*DELTA(THETA)                       00013700
C NDH = NUMBER OF POINTS IN TABLE, MAAX= 50                             00013710
C                                                                       00013720
C     CALCULATE PARTIAL SUM OF D * DELTA(THETA)                         00013730
C                                                                       00013740
      DO 60 NS=1,10                                                     00013750
      NUMDH(NS) = 0                                                     00013760
      IF (DHTAB(1,1,NS) .EQ. 0.) GO TO 60                               00013770
      DHTAB(1,4,NS)= DHTAB(1,2,NS) * (DHTAB(2,1,NS) - DHTAB(1,1,NS))    00013780
      DO  55  I = 2,50                                                  00013790
      IF (DHTAB(I,1,NS) .EQ. 0.) GO TO 60                               00013800
      NUMDH(NS) = I                                                     00013810
      DHTAB(I,4,NS) = DHTAB(I-1,4,NS) +DHTAB(I,2,NS) * (DHTAB(I,1,NS)-  00013820
     &                DHTAB(I-1,1,NS) )                                 00013830
 55   CONTINUE                                                          00013840
 60   CONTINUE                                                          00013850
C  PRINT DHTAB ON OPTION                                                00013860
      IF (IOPT(4) .EQ. 0) GO TO 66                                      00013870
```

SCRAM Program Listing (Continued)

```
      DO 63 I=1,10
      IF (DHTAB(1,1,I) .EQ. 0.) GO TO 63
      WRITE (6,1006) I
 1006 FORMAT('1', 50X 'DHTAB ARRAY, SOIL TYPE',I3//
     1 20X'THETA',10X'D(THETA) DIFFUSIVITY', 3X 'H(THETA) PRESSURE HEAD'
     2, 6X 'SIGMA D DELTA THETA' //)
      N = NUMDH(I)
      WRITE(6,1007) (J,(DHTAB(J,K,I),K=1,4),J=1,N)
 1007 FORMAT(I4,4E25.6)
 63   CONTINUE
C  INITIALIZE CIT, CUMULATIVE INFILTRATION
C  CALCULATE SUMIN, CUMULATIVE WATER IN
C  CALCULATE SUMRN, CUMULATIVE RAINFALL
   64 CONTINUE
      IF(IOPT(1).NE. 0) RETURN
      SUMRN = 0.
      SUMIN = 0.
      DO 70 I=1,NZN
      CIT(I) = 0.
      SUMIN = SUMIN + THETA(1,I)*SUB(9,I)*SUB(2,I)/1000.
      NS = SUB(8,I)
      CITTI=0.
      DO 65 J=2,NS
 65   CITTI  = CITTI  + THETA(J,I)*SUB(9,I)
 70   SUMIN = SUMIN + CITTI *SUB(2,I)/1000.
      RETURN
  999 STOP
      END
```

SCRAM Program Listing (Continued)

```
      FUNCTION ITABLE  (ARG, TAB, N)
C
C  FUNCTION SUBPROGRAM CALLED BY SUBROUTINE WATER
C
      DIMENSION TAB(N)
      IF(ARG - TAB(1)) 1, 1, 2
1     ITABLE = 1
      RETURN
2     IF(ARG - TAB(N)) 4, 3, 3
3     ITABLE = N
      RETURN
4     N1 = 1
      N3 = N
10    N2 = (N1 + N3) / 2
      IF(N1 .EQ. N2) GO TO 100
      IF(ARG - TAB(N2)) 20, 100, 50
20    N3 = N2
      GO TO 10
100   ITABLE = N2
      RETURN
50    N1 = N2
      GO TO 10
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE NEWRAP(L,NZ,ID,ALP,CEST)
C
      COMMON /AQUATA/ C(27,20), S(27,20), NNT, SSS(27,20)
     1      ,DC(27), VEL(27), THETJ(27), B(27),KDES(27,20),CMASUM(27,20),
     2      THETX,ZMAX, H, KTIME,II, A, DENOM,DENMA,INDEX(20),INDEXI(20),
     3      ANT, AX, IISAVE, IGOR, NVAL(20),DESRO, SPONT,ALOW(20),DVST,
     4      THETAT, SUMC(27), SUMS(27),CUMAD, CUMDS,PTOT(20) ,C1(27,20)
     5      , VPAST(27,20),KSW(20),INTGER ,NOSTOP(20),ADRO,DSRO
      COMMON /WATERD/ NZN, RAINR(20),  THETA(27,20),THETN(27,20)
      REAL K,NEXP,KDES
      COMMON/CONST/CON(50)
      EQUIVALENCE (CON(1),RHO), (CON(3),NEXP),(CON(10),K),(CON(9),AB)
      NAMELIST /CSS/RHO,RHOK,PR,FEST,FPEST,KDES
C
C  THETA ARE OLD VALUES AND THETN ARE NEW VALUES WITH THE EFFECT OF
C     EVAPOT FROM THE PREVIOUS TIME STEP.  AT THIS POINT EVAPOT HAS
C     ALREADY BEEN CALLED FOR THIS TIME , BUT BALANC IS NOT CALLED
C     UNTIL THE END OF PROGRAM---EFFECT OF EVAPOT IS NOT INCORPORATED
C     UNTIL THEN FOR THE PRESENT TIME STEP.
C
C  (COUNT IN THETA IS OFFSET BY  1 -- BY THE DEFINITION OF LAYERS FOR
C      C  AND THETA)
C
C       AB IS FLAG FOR ADSORPTION OR DESORPTION
      IF(CEST.LE.0.) GO TO 25
      IF(ID.GT.1) GO TO 30
      RHOK= RHO *K
      PR = NEXP
C  SET UP FIRST ESTIMATE FOR C
      CEST = THETA(L+1,NZ) * C(L,NZ) / THETN(L+1,NZ)
      GO TO 40
C     DESORPTION
   30 RHOK = RHO * KDES(L,NZ) * AB
      PR = 1./AB
   40 CONTINUE
      DO 10 I=1,20
      FEST= THETN(L+1,NZ) *CEST + RHOK* (CEST**PR) -ALP
      FPEST= THETN(L+1,NZ) + RHOK*(CEST**(PR-1.))* PR
      CNEW= CEST - FEST/ FPEST
      IF(CNEW.GT.0.) GO TO 41
      CEST = CEST / 2.
      GO TO 10
   41 CONTINUE
      CTEST= CEST/CNEW
      IF(ABS(ALOG(CTEST)) .LE. 0.001)  GO TO 20
   42 CONTINUE
C     WRITE(6,100) CEST,CNEW,ALP
  100 FORMAT (1X, 'I.R. NEWRAP', 3X, 'CEST=' E15.6,5X, 'CNEW=' E15.6
     1,5X,'ALP=' E15.6)
      CEST = CNEW
   10 CONTINUE
C
C  NO CONVERGENCE AFTER 20 STEPS--PRINT ERROR MESSAGE
C   DO NOT ALTER ORIGINAL C(L,NZ)
```

SCRAM Program Listing (Continued)

```

C
      WRITE(6,200) L,NZ,C(L,NZ), CNEW
  200 FORMAT ('0 S.R. NEWRAP, NO CONVERGENCE  AFTER 20 STEPS, LAYER='
     1   I5,' AND ZONE=' ,I5/ 10X, ' C(L,NZ)= ',E15.6,3X,' CNEW=' E15.6)
   25 C(L,NZ)= 0.0
      RETURN
   20 C(L,NZ)= CNEW
      RETURN
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE OUTPLT
C
C  MAKES PRINTER PLOTS AND PUNCHES CARDS FOR PLOTS OF:
C      TIME VS RUNOFF
C      TIME VS RUNOFF RATE
C      TIME VS RUNOFF/RAINFALL
C      TIME VS SEDIMENT
C
      COMMON /PLOTS/ KTPLT,ARAY(100,9) ,PC(27)
C
      COMMON /CONST/ CON(50),IOPT(50)
C
C
      COMMON /ADDATA/ C(27,20), S(27,20), KNT
C
       DIMENSION VMAX(7),VMIN(7)
      DATA VMAX,VMIN /14*0./
      DATA ANEG/-1./
C
      DIMENSION YLIST(100)
      DATA YLIST /100*1.E30/
C
      DIMENSION TITL(20,8)
      DATA TITL /  4*' ',
     1     'TOTA','L RU','NOFF',' (LI','TERS',')  ',14*' ',
     2     'RUNO','FF R','ATE ','(LIT','ERS/','SEC)',14*' ',
     3     'RUNO','FF/T','OTAL',' RAI','N (P','ERCE','NT) ',13*' ',
     4     'SEDI','MENT',' RAT','E (K','G/HR','/HEC','TARE',')   ',12*' '
     5.    'SEDI','MENT',' LOA','D (K','G/HE','CTAR','E)  ',13*' ',
     6      'SEDI','MENT','/RUN','OFF ','(GM/','LITE','R)  ', 9*' ',
     7  4*' ','PEST', '. LO','SS O','N SE','D.  ',  11*' ',
     8  4*' ','PEST','. LO','SS I','N H2','O   ', 11*' '  /
C
      IF((IOPT(9).EQ.1). AND. (IOPT(10).EQ.0 )) RETURN
      IF (KTPLT .EQ. 0) GO TO 99
      WRITE (6,1000)
      DO 5 I=2,7
      VMIN(I) = 1.E30
 5    VMAX(I) = 0.
      DO 10 I=1,KTPLT
      ARAY(I,1) = ARAY(I,1) + 5.
      WRITE (6,1001) I,(ARAY(I,J),J=1,9)
      DO 10 J=2,9
      VMIN(J) = AMIN1(VMIN(J),ARAY(I,J))
      VMAX(J) = AMAX1(VMAX(J),ARAY(I,J))
 10   CONTINUE
      VMIN(1) = INT(ARAY(1,1)/25.)*25
      VMAX(1) = (INT(ARAY(KTPLT,1)/25.)+1)*25.
      IF (VMAX(4) .EQ. VMIN(4)) GO TO 15
      VMIN(4) = 0.
      VMAX(4) = 100.
 15   CONTINUE
C
      DO 20 J=2,7
```

SCRAM Program Listing (Continued)

```
      IF (VMIN(J) .EQ. VMAX(J))  GO TO 20
      CALL PPLOT (TITL(1,J-1),ARAY(1,1),ARAY(1,J),KTPLT,TLIST,VMIN(1),
     1     VMAX(1),VMIN(J),VMAX(J),1)
 20   CONTINUE
C  PUNCH CARDS IF REQUESTED
      IF (IOPT(5) .EQ. 0) GO TO 99
      VMAX(3) = VMAX(3)*60.
      DO 35 I=2,9
      IF((I.EQ.2).OR.(I.EQ.4).OR.(I.EQ.5).OR.(I .EQ.6)) GO TO 35
      IF (VMIN(I) .EQ. VMAX(I)) GO TO 35
      WRITE (7,1002) VMAX(1)
 1002 FORMAT('TIME (MIN)',34XF10.0,24X'10')
      WRITE(7,1003)(TITL(J,I-1),J=5,11),VMAX(I)
 1003 FORMAT(7A4,16X F10.3,24X'20')
      DO 30 J=1,KTPLT
      IF (I.EQ.3) ARAY(J,3) = ARAY(J,3)*60.
 30   WRITE(7,1004) ARAY(J,1),ARAY(J,I)
 1004 FORMAT(2F9.2)
      WRITE(7,1004) ANEG,ANEG
 35   CONTINUE
C  PUNCH CARDS FOR % PESTICIDE
      WRITE(7,2000)
 2000 FORMAT(' PROFILE DEPTH VS % PESTICIDE  ')
      DO 100 I=1,KNT
      EI=I
      WRITE(7,1004) EI,PC(I)
  100 CONTINUE
      WRITE(7,1004) ANEG,ANEG
 99   RETURN
 1000 FORMAT('1 NO.',1X, 'TIME',' TOTAL RUNOFF',' RUNOFF RATE',
     1 ' PERCENT RUNOFF', ' SEDIMENT RATE',' SEDIMENT LOAD',
     2  ' SEDIMENT/R.O.', ' PEST. ON SED',' PEST. ON WATER' //)
 1001 FORMAT(I5,F9.2,8E12.5)
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE OUTPUT(ITYP)
C
      COMMON /TIMES/ TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,
     1    EPATM
      REAL*8 TOLD,TNEW,DT,DTOLD,TCUT,TSTRT,TSTCP,TRAIN,PIN,EPATM
C
      COMMON /SEDATA/SUB(10,20),ADJLI(21),ADJLO(20),RNF(4,20),INF(4,20)
     1    ,SEDWAT,HECT,AK1(10),AK2(10),ST(10),ADJLL
     2    ,XADJLI
C
      COMMON /WATERD/ NZN, RAINR(20), THETA(27,20),THETN(27,20),CUMRO
     1     ,CUMFLT,DHTAB(50,4,10),NUMDH(10),RINF(20),CIT(20),QTOT(27,20)
     2     ,Q(27,20),SUMRN,WATROT,SUMIN,ROR,RDT ,XUMRO
C
      COMMON /EVAPIN/ ELE2, DATA(5,20), DATAN(5,20),
     1                RUFF,SRES,DELGAM(121),SVPRES(121),VPRE2,VPDEF,
     2     ATRES,POEVAP,TOTVAP
C
      COMMON /CONST/ CON(50),IOPT(50),KPEST
C
      COMMON /ADDATA/ C(27,20), S(27,20), KNT, SSS(27,20)
     1     ,DC(27), VEL(27), THETJ(27), B(27),KDES(27,20),CMAXUM(27,20),
     2     THETX,XMAX, H, KTIME,II, A, DENOM,DENAM,INDEX(20),INDEX1(20),
     3     ANT, AX, IISAVE, IGOR, NVAL(20),DESKRO, XPONT,KLEW1(20),DVST,
     4     THETAT, SUMC(27), SUMS(27),CUMAD, CUMDS,PTOT(20) ,C1(27,20)
     5     , VPAST(27,20),KSM(20),INTGER ,NOSTOP(20),ADRX,DSRX
     6    ,TOTAD,TOTDS,ZROC(27,20),CCL(27),SSL(27),TOT(27)
C
      COMMON /PLOTS/ KTPLT,ARAY(100,9) ,PC(27)
C
      REAL*8 TGO /0./
      DIMENSION D(3)
      REAL*8 TYPE(5)/' INITIAL',' NORMAL','RAINFALL','   FINAL',
     1    'SPECIAL '/
      DATA IKT /-1/
C
C  IOPT(16)  NE  0 IS TO PRINT VOLITALIZATION OUTPUT ONLY
      IF(IOPT(16) .NE.0)          RETURN
C
      XSEDKG= XADJLI/1000.
      SEDKG = ADJLI(21)/1000.
      IKT = IKT + 1
      IF((ITYP.EQ.3) .OR. (ITYP.EQ.5))  GO TO 207
      IF (MOD(IKT, IOPT(9)) .NE. 0 .AND. ITYP .NE. 4) GO TO 30
  207 CONTINUE
      WRITE(6,1000) TYPE(ITYP)
 1000 FORMAT('1 ',A8,' CONDITION OUTPUT')
   30 CONTINUE
      CALL DATOUT(TNEW,D,0)
      WRITE (6,1007)(RAINR(I),I=1,NZN)
 1007 FORMAT('0   RAINFALL RATE =','CM/SEC'/(1X,10E12.4/))
      CALL PRNTTH
      IF (IOPT(2) .EQ. 0) GO TO 999
C  SAVE DATA FOR WARM START
```

SCRAM Program Listing (Continued)

```
      REWIND 13
      WRITE (13) ADJLI, CUMRO, KPEST, THETA, C, S ,TSTRT,TOLD
     1 , CUMDS,CUMAD,VPAST,CMAXUM,NOSTOP,INDEX,INDEX1,KLEM1,KDES,KSW
     2  ,XUMRO,C1, TOTAD, TOTDS, XADJLI  ,DT     ,CIT
     3  ,THEW,SUMRN,SUMIN,TCTVAP,CUMFLT,NVAL ,THETN
  999 CONTINUE
      IF (ITYP.EQ.1) GO TO 30
C  OUTPUT SEDIMENT LOAD DISTRIBUTION
      WRITE (6,1001)
 1001 FORMAT('1   ZONE #  SEDIMENT',8X 'RUNOFF',  2X,'TOTAL'  /
     1 14X 'LOAD' ,11X 'RATE', 3X, 'PESTICIDE'  /
     2 11X 'GM/CM/SEC',9X 'CM/S', 3X, 'MICROGRAMS'  //)
      ISW=1
      DO 20 I=1,NZN
      RR = THETN(1,I)*SUB(9,I)/DT
      ELF = ADJLO(I) / (SUB(5,I)*DT)
      IF((RR.NE.O.) .OR. (ELF.NE.0. )) ISW=0
 20   WRITE(6,1002) I,ELF,RR, PTOT(I)
 1002 FORMAT(I10,4E12.4)
      IF(IOPT(12).NE.0)  GO TO 202
      WRITE(6,2000)
 2000 FORMAT('0',12X,'AVERAGE',3X,'AVERAGE',7X,'TOTAL'/
     1  3X,'PROFILE',3X,'PESTICIDE',3X,'PESTICIDE',3X,'PESTICIDE'/
     2  5X,'DEPTH',3X,'DISSOLVED',4X,'ADSORBED'/
     3  12X,'MICROGRAMS',2X,'MICROGRAMS'  ,2X, 'MICROGRAMS')
C
C  VALUES OF C  AND S  ARE BEFORE ADJUSTMENT TO FIRST LAYER
C
C
C  C(LAYER,ZONE)
C  KNT IS MAX # OF LAYERS FOR C AND S
      TPC=0.0
      DO 40 I=1,KNT
      PC(I) = TOT(I)
      TPC = TPC + TOT(I)
      WRITE(6,1002) I,CCL(I),SSL(I),TOT(I)
 40   CONTINUE
      DO 400 I=1,KNT
 400  PC(I)= PC(I)/ TPC *100.
 22   CONTINUE
      RATDS=0.
      RATAD=0.
      IF(RDT.NE.O.) RATDS = DSRX/RDT *1.F+6
      IF(ADJLL.NE.O.) RATAD= ADRX/ADJLL
      XDS= CUMDS        /HECT
      XAD= CUMAD*1.E-6 /HECT
 202  CONTINUE
      WRITE(6,1003) XUMRO, XDS, RATDS, XSEDKG, XAD, RATAD
 1003 FORMAT('0',  3X, 'ACCUMULATED RUNOFF:', 33X, 'ACCUMULATED PESTICID
     1E LOSS:',18X,'INSTANTANEOUS PESTICIDE LOSS'/8X,
     2              'WATER =' ,F12.0, 'LITERS', 28X,'IN WATER =',F12.2,
     3'GRAMS/HECTARE',5X, F12.2, 'MICROGRAMS/LITER' /
     3                 5X, 'SEDIMENT =',F12.0,'KILOGRAMS',22X,
     4  'ON SEDIMENT =',F12.2, 'GRAMS/HECTARE',
```

SCRAM Program Listing (Continued)

```
     >  5X, F12.2, 'MICROGRAMS/GRAM'  / )
C
C  RLAD= RATE OF LOSS (UG/G/HR)
C  RLDS= RATE OF LOSS (UG/L/HR )
      RLAD= (RATAD/DT) * 3600.
      RLDS= (RATUS/DT) *3600.
C  CON(12) IS AMT  OF PESTICIDE APPLIED ( UG/CM**2)
C  PCAD,PCDS= % OF THE AMT OF PEST APPLIED
C  ARCM = TOTAL AREA OF WATERSHED(CM**2)
      ARCM=0.
      DO 31 I=1,NZN
   31 ARCM= ARCM + SUB(2,I)
      COSDS=CUMDS*1.E+6
      CADAD=CUMAD
      PCDS= (COSDS/(CON(12)* ARCM))*100.
      PCAD= (CADAD/(CON(12)*ARCM))*100.
C
      WRITE(6,1004) PCDS, RLDS, TOTVAP, PCAD, RLAD
 1004 FORMAT('0   TOTAL WATER LOSS', 36X, '% OF PESTICIDE APPLIED' ,23X,
     1 'RATE OF PESTICIDE LOSS'/7X,'FROM EVAPOTRANSPIRATION'
     2          ,30X,'IN WATER =', F7.4, 23X, F12.2,
     3 'MICROGRAMS/LITER/HR' / 7X, '=', F12.0, ' LITERS',
     *                              30X,'ON SEDIMENT =', F7.4,23X,
     4                  F12.2, 'MICROGRAMS/GRAM/HR'     )
      WRITE(6,1005) CUMFLT
 1005 FORMAT('0   ACCUMULATED INFILTRATION' /
     1 4X,'WATER LOSS =', F12.0, ' LITERS' )
      WRITE (6,1006) SUMIN,WATROT
 1006 FORMAT('0  WATER BALANCE:'/'   WATER IN = ',E14.7,' LITERS'/
     1     '   WATER OUT =',E14.7,' LITERS')
      DO 1009 I=1,NZN
      WRITE(6,1008) I,RINF(I)
 1008 FORMAT('     ZONE ',I2,5X,'INFILTRATION RATE=',E12.4,' CM/SEC')
 1009 CONTINUE
 30   IF (CUMRO+SEDKG .EQ. 0.) GO TO 99
      IF (TGO .EQ. 0.) TGO = TNEW
      IF (KTPLT .LT. 100) GO TO 35
      CALL OUTPLT
      KTPLT = 0
 35   KTPLT = KTPLT + 1
      T = TNEW-TGO
      PCT = 0.
      IF (SUMRN .GT. 0.) PCT = CUMRO/SUMRN
      ARAY(KTPLT,1) = T/60.
      ARAY(KTPLT,2) = CUMRO
      ARAY(KTPLT,3) = ROR
      ARAY(KTPLT,4) = PCT*100.
      ARAY(KTPLT,5) = SEDRAT*3.6/HECT
      ARAY(KTPLT,6) = SEDKG/HECT
      ARAY(KTPLT,7) = 0.
      ARAY(KTPLT,8)= CUMAD
      ARAY(KTPLT,9)= CUMDS
      IF (ROR. NE. 0.)
     *ARAY(KTPLT,7) = SEDRAT/ROR
```

SCRAM Program Listing (Continued)

```
99 CONTINUE
   IF(ISW.NE.1)  RETURN
   CUMRO=0.
   XADJLI=0.0
   CUMAD=0.
   CUMDS=0.
   RETURN
   END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE PRNTTH
C
C  SUBROUTINE TO PRINT VALUES OF THETA, CIT, C, AND S
C
      COMMON /SEDATA/SUB(10,20),ADJLI(21),ADJLO(20),RNF(4,20),INF(4,20)
C
      COMMON /WATERC/ NZN, RAINR(20),  THETA(27,20),THETN(27,20),CUMRO
     1      ,CUMFLT,DHTAB(50,4,10),NUMDH(10),RINF(20),CIT(20),QTOT(27,20)
     2      ,Q(27,20)
C
      COMMON /ADDATA/ C(27,20), S(27,20), KNT
C
C  NTH =MAX VALUES OF THETA = (NO. OF LAYERS) = SUB(8,I)
C  TO PRINT OUT VALUES OF THETA(NTH,NZN)
      WRITE(6,1000)
 1000 FORMAT('0', 50X'ZONE DEPTH PROFILE')
      NTH=1
      TH= 1.0
      DO 40  I=1,NZN
   40 TH  = MAX1(TH,SUB(8,I) )
      NTH=TH
      ISW=1
      NA=1
      NB=NZN
      IF(NB.LE.10) GO TO 50
      NB=10
   50 CONTINUE
      WRITE (6,310)
  310 FORMAT('0',55X,'ZONE #'  )
      WRITE (6,320) (I1,I1=NA,NB)
  320 FORMAT(  ' PROFILE',3X, 10(5X,I2,4X) )
      WRITE(6,321)
  321 FORMAT(' THETA')
      DO 340 I2=1,NTH
  340 WRITE (6,330)  I2,((THETA(I2,I1), I1=NA,NB)    )
  330 FORMAT(3X, I2,4X, 10F11.3  )
      WRITE(6,333)(CIT(I1),I1=NA,NB)
  333 FORMAT('   CIT   ',10F11.3)
      IF (KNT .EQ. 0) GO TO 400
      WRITE (6,430)
  430 FORMAT(' DISSOLVED PESTICIDE')
      DO 440 I2=1,KNT
  440 WRITE (6,450) I2,(C(I2,I1),I1=NA,NB)
  450 FORMAT(3XI2,4X10E11.3)
      WRITE(6,460)
  460 FORMAT(' ADSORBED PESTICIDE')
      DO 470 I2=1,KNT
  470 WRITE(6,450) I2,(S(I2,I1),I1=NA,NB)
  400 GO TO (51,52), ISW
   51 IF(NZN.LE.10) GO TO 52
      NA= NB+1
      NB= NZN
      ISW = 2
      GO TO 50
```

SCRAM Program Listing (Continued)

```
52 CONTINUE                                                             00018140
   RETURN                                                               00018150
   END                                                                  00018160
```

SCRAM Program Listing (Continued)

```
      FUNCTION RK(M,T)
C
C   FUNCTION SUBPROGRAM CALLED BY SUBROUTINE DEGR
C
C
      REAL M,MOPT,K,KOPT
C
      COMMON /CONST/ CON(50)
      EQUIVALENCE (CON(22),KOPT),(CON(23),MOPT),(CON(24),TOPT),
     &             (CON(25),TMAX),(CON(26),AK  ),(CON(27),BK  )
C
      RK =-KOPT*EXP(AK*(M-MOPT)**2)* EXP(BK*(T-TOPT)) *
     &  ((TMAX-T)/(TMAX-TOPT))**(BK*(TMAX-TOPT))
      RETURN
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE RUNGE(L,KRHO,NZ)
C
      REAL K,KRHO,KDES
C  NOTE CHANGES IN COMMON BETWEEN ADDE AND RUNGE
C    VARIABLES IN:
C     RUNGE       ADDE
C     U           C
C     D           DC
C     K           KTIME
C     DVS         DVST
C     L2          II
      COMMON /ADDATA/ U(27,20), S(27,20), KNT, SSS(27,20)
     1      ,D (27), VEL(27), THETJ(27), B(27),KDES(27,20),CMAXUM(27,20),
     2      THETX, XMAX, H, K  , L2, A, DENOM,DENAM,INDEX(20),INDEX1(20),
     3      ANT, AX, IISAVE, IGOR, NVAL(20), DESKRO, XPONT,KLEW1(20),DVS,
     4      THETAT, SUMC(27), SUMS(27),CUMAD, CUMDS,PTOT(20) ,C1(27,20)
     5      , VPAST(27,20),KSW(20),INTGER ,NOSTOP(20)
C
      DIMENSION R(27)
      NAMELIST /BUG/U,L2,INDEX,INDEX1
C
C  CALCULATES NEW VALUES OF C/CO USING OLD VALUES FOR THE EXPRESSION
C  S=KADS*C**N. STATEMENTS UP TO 270 COMPUTE HERBICIDE OR PESTICIDE
C  CONCENTRATIONS, AND STATEMENTS 280 TO 260 COMPUTE CLORIDE CONCEN-
C  TRATIONS IF NOCLOR=1.
C
      I1=INDEX(NZ)
      CPAST= U(I1   ,NZ)
      R(1)= 0
      R(L)= 0
      I11= INDEX1(NZ)
      DO 30 I=2,I11
      IF(U(I,NZ)) 40,40,50
   40 R(I)= A*(U(I-1,NZ)+U(I+1,NZ))+B(I)*U(I-1,NZ)
      GO TO 29
   50 C= 1.+KDES(I,NZ)*D(I)*U(I,NZ)**ANT
      E=B(I)/C
      C=A/C
      R(I)= U(I,NZ)+(C*(U(I-1,NZ)-2.*U(I,NZ)+U(I+1,NZ))-E*(U(I,NZ)
     1  -U(I-1,NZ)))
   29 U(I,NZ)= ABS(R(I))
   30 CONTINUE
      I1= INDEX(NZ)
      DO 100 I=I1    ,L2
      IF(U(I,NZ)) 10,10,20
   10 R(I)= A*(U(I-1,NZ)+U(I+1,NZ))+B(I)*U(I-1,NZ)
      GO TO 99
   20 C=1.+KRHO*D(I)*U(I,NZ)**AX
       E= B(I)/C
      C=A/C
      R(I)= U(I,NZ)+(C*(U(I-1,NZ)-2.*U(I,NZ)+U(I+1,NZ))-E*(U(I,NZ)
     1  -U(I-1,NZ)))
   99 U(I,NZ)= ABS(R(I))
  100 CONTINUE
```

SCRAM Program Listing (Continued)

```
      U(1,NZ)= ABS(U(2,NZ)*DENOM)
C     IF(IREDIS .EQ. 2) U(1,NZ) = U(1,NZ)-DVS*U(1,NZ)*R/H
      U(L,NZ)= ABS(U(L2,NZ)*DENAM)
      IF(NOSTOP(NZ) .EQ. 1) GO TO 270
      CMAX= 0
      K1= KLEW1(NZ)
      DO 60 I=K1   ,L2
      IF(CMAXUM(I,NZ) .LT. U(I,NZ)) CMAXUM(I,NZ)= U(I,NZ)
      IF(U(I,NZ)-CMAX) 60,60,110
  110 INDEX(NZ)=I
      CMAX= U(I,NZ)
   60  CONTINUE
      INDEX1(NZ)= INDEX(NZ) +1
      IF(INDEX1(NZ) .GT. L2) NOSTOP(NZ)=1
      IF(INDEX1(NZ) .GT.L2) INDEX1(NZ) = INDEX(NZ)
      IF((KLEW1(NZ) .LT. INDEX(NZ)) .AND. (INDEX(NZ) .GT. 2)) GO TO 150
      I1= INDEX(NZ)
      IF(CPAST .LT. U(I1   ,NZ)) GO TO 270
      INDEX(NZ)= INDEX1(NZ)
  150 NIDEX= INDEX(NZ)-1
      K1= KLEW1(NZ)
      DO 140  I=K1   ,NIDEX
  140 KDES(I,NZ)= DESKRO*CMAXUM(I,NZ)**XPONT
      KLEW1(NZ)= INDEX(NZ)
  270 CONTINUE
C
C 270 IF(NOCLOR .NE. 1) RETURN
C     DO 280 I=2,L2
C     R(I)= A*(CLORID(I+1)-2.*CLORID(I)+CLORID(I-1))-B(I)*(CLORID(I)-
C    * CLORID(I-1))+CLORID(I)
C 280 CONTINUE
C     DO 250 I=2,L2
C 250 CLORID(I)= R(I)
C     CLORID(1)= CLORID(2)*DENOM
C     CLORID(L)= CLORID(L2)*DENAM
C
  280 RETURN
      END
      SUBROUTINE SED
C
C
C   SEDIMENT CALCULATION SUBROUTINE, CALCULATES SEDIMENT FLOW
C
      COMMON /SEDATA/SUB(13,20),ADJLI(21),ADJLO(20),RNF(4,20),INF(4,20)
     1     ,SEDRAT, HECT, AK1(10),AK2(10),ST(10)
C
C
C   SUB(K,I)= SUBPLOT DESCRIPTION OF EACH ZONE
C   ADJLI= INPUT ADJUSTED SEDIMENT LOAD(GM)
C   ADJLO= OUTPUT ADJUSTED SEDIMENT LOAD(GM)
C   RNF(J,I)= % RUNOFF TO CORRESPONDING INF ZONE
C   INF(J,I)= ZONE TO WHICH RUNOFF FROM ZONE I RUNS
C   SEDRAT= SEDIMENT LOSS RATE(GM/SEC)
C   HECT= WATERSHED AREA (HECTARES)
C
      COMMON /CONST/ CON(50),IOPT(50),NPEST
      EQUIVALENCE (CON(8),NDD),(CON(19),ALIM)
C
      COMMON /WATERD/ NZN, RAINR(20),  THETA(27,20),THETN(27,20)
C
      COMMON /TIMES/ TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PEN,
     1     EPATH, PRINT(3), PRODUT(3), PESTH ,DATPL,DATMAT,DATHAR
      REAL*8 TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PEN,EPATH,PESTH
      REAL*8 DATPL,DATMAT,DATHAR
C
      DIMENSION DF(2),ELF(2)
      DIMENSION TEMP(10)
      NAMELIST /TEST/TOLD,TNEW,DT,TRAIN,TOUT,DTDRY,EPATH,DTWET,DTOLD
C
C   SAVE ORIGINAL VALUES
      DO 20 I= 1,10
   20 TEMP(I)= ST(I)
C
C   ALLOW FOR MODICATION OF ST(=K3), CONSTANTS FOR SEDI
C      TO INCLUDE EFFECT OF CANOPY COVER.
C   VALUE FOR CANOPY COVER IS STORED IN CON(20)--DEFAULT VALUE  IS 0.9
      RATIO= (DATMAT-TOLD )/ (DATMAT-DATPL)
      ALF= CON(20)- RATIO *CON(20)
      IF(( TOLD .LT.DATPL) .OR.(TOLD .GT.DATHAR )) ALF=0.0
      IF(( TOLD .GE.DATMAT).OR.( TOLD .LE. DATHAR)) ALF= CON(20)
      DO 85 I=1,10
   85 ST(I)= ST(I)*(1.0-ALF)
C
C
C   FOLLOWING IS FOR CHANGING AK1(I)
C
C   DETERMINE # OF MONTHS SINCE PLANTING( TOLD,ETC. ARE IN DPSEC)
C
      EMO= (TOLD-DATPL) /(60.*60.*24.*30. )
      DO 95 I=1,10
      AK1(I)= 10.+ 300.* EXP(-EMO)
      IF (EMO.GT.6.)  AK1(I) = 10.
```

SCRAM Program Listing (Continued)

```
   95 CONTINUE
C     WRITE (6,99) EMO, AK1
   99 FORMAT( ' SEDI' , 5X,  11E10.3)
      DO 10 N=1,NZN
      ROMAX = SUB(10,N)*DT
      AVG = THETN(1,N)*SUB(9,N)*AMIN1(1.,ROMAX)
      Z = (WD*AVG*SUB(3,N))**1.5
      ELFB = 0.
      IF (Z.EQ.0.) GO TO 9
      ITYP = SUB(1,N)
      IF (ITYP.GT.10) CALL ERROR(5)
      TCB = AK1(ITYP)*Z
      DCB = AK2(ITYP)*Z
      DFI = ST(ITYP)*RAINR(N)**2
      IF(RAINR(N).EQ.0. ) DFI= ST(ITYP)*(5.E-4**2)
      ALPH = SUB(4,N)*DCB/TCB
      THET = SUB(4,N)*DFI/TCB
      IF (ADJLI(N) .EQ. 0.) GO TO 12
C
C  CALCULATE INITIAL CONSTANT OF INTEGRATION
C  (USING LOAD CARRIED FROM LAST SLOPE BOTTOM)
C
      ELFB = ADJLI(N)/(SUB(5,N)*DTOLD)
C  DROP EXCESS SEDIMENT
      IF (ELFB .GT. TCB*ALIM) ELFB = TCB*ALIM
 12   C = -ELFB/TCB
      X = 1./SUB(7,N)
      DF(1) = ((((1.-THET)/ALPH)*(1.-EXP(-ALPH*X)))+C*EXP(-ALPH*X))
     1 *DCB
      ELF(1) = (X-(DF(1)/DCB))*TCB
      ELF(2) = ELF(1)
      IF(SUB(7,N).EQ.1.) GO TO 6
      INCR = SUB(7,N)
C  CHECK DETACHMENT RATE AND LOAD INCR POINTS
      DO 5 K=2,INCR
      DIST = (SUB(4,N)/SUB(7,N))*K
      X = DIST/SUB(4,N)
      DF(2) = ((((1.-THET)/ALPH)*(1.-EXP(-ALPH*X)))+C*EXP(-ALPH*X))
     1 *DCB
      ELF(2) = (X-(DF(2)/DCB))*TCB
C  CHECK TO SEE IF NEW CONSTANT NEEDS TO BE CALCULATED
      IF (DF(2)) 1,3,2
  1   IF (DF(   1)+DF(2).GT.DF(2)) GO TO 3
      GO TO 4
  2   IF (DF(   1)+DF(2).LT.DF(2)) GO TO 3
      GO TO 4
C  CALCULATE NEW CONSTANT
  3   X = X-(1./(2.*SUB(7,N)))
      C = ((THET-1.)/ALPH)*(1.-EXP(-ALPH*X))*EXP(ALPH*X)
  4   CONTINUE
      DF(1) = DF(2)
      ELF(1) = ELF(2)
  5   CONTINUE
  6   ELFB = ELF(2)
```

SCRAM Program Listing (Continued)

```
C                                                                       00020320
C  CALCULATE OUTPUT ADJUSTED SEDIMENT LOAD(GM)                          00020330
C                                                                       00020340
 9     ADJLO(N) = ELFB*SUB(5,N)*DT                                      00020350
 10    CONTINUE                                                         00020360
C  RESTORE ST(I)                                                        00020370
       DO 30 I=1,10                                                     00020380
    30 ST(I)= TEMP(I)                                                   00020390
       RETURN                                                           00020400
       END                                                              00020410
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE SEQDAT
C
C  READ SEQUENTIAL DATA
C
      REAL*8 SEC,SEC1
      DIMENSION IFLG(9), D(6),CNVRTR(7),CNVRTW(4),CNVRTS(2),CNVRTP(2)
     &     ,DS(6)
C
      DIMENSION RAINR(20), RAML(20), RAINRT(20), RTP(20), WIND(20),
     &   TEMP(20), RAD(20), PRES(20), HUM(20), RMF(20), EMF(20)
C
      DATA RTP/20*1.E33/
      DATA CNVRTR /10., .21, 2.54, 30.48, 3*0./
      DATA CNVRTW /100., 30.48, 44.703, 51.444/
      DATA CNVRTS /1., 1./
      DATA CNVRTP /1013.2, 68.9507/
      DATA RAIN, DAYS, ANET / 'R   ','D   ','N   '/
C
C
      ISW=1
      KTR=0
      ETIME=0.0
C     PUNCH 500
  500 FORMAT(' ELAPSED TIME(SEC)  VS  RAIN RATE(CM/SEC)  ')
      KTEPA=0
C  READ HEADER CARD
 10   READ (4,1000,END=50)  TYPE,IFLG
 1000 FORMAT(A1,9X 9I2)
      SV = 0.
      SV1 = 0.
      SV2 = 0.
      IF (TYPE .NE. RAIN) GO TO 30
C  RAINFALL CARDS
      WRITE (6,1004)
 1004 FORMAT('1  RAINFALL HISTORY'//'  YEAR MONTH  DAY  HOUR  MINUTE SEC
     1AND RAIN(CM/SEC)'//)
C
C  THIS NZN IS THE SAME AS THE ONE CALC. IN S.R. INPUT
C  WE HAVE TO READ IT HERE BECAUSE S.R. INPUT IS CALLED AFTER S.R.SEQDAT
C
      READ(4,5) NZN
    5 FORMAT(I5)
C
C  RMF(I) IS ARRAY OF MULTIPLYING FACTORS
C  IF RMF(1) EQ -1. , READ A SET OF RAIN CARDS FOR EACH TIME
C
      READ(4,1010) (RMF(I), I=1,NZN)
 1010 FORMAT(20F4.0)
      IF(RMF(1).EQ. -1.)  GO TO 60
      ISW=2
      READ (4,1001,END=22) D,RAINR(1)
      DO 44 I=2,NZN
   44 RAINR(I)= RAINR(1) * RMF(I)
      GO TO 200
```

SCRAM Program Listing (Continued)

```
   60 DO 61 I=1,NZN
      READ (4,1001,END=22) D,RAINR(I)
      IF(D(1).EQ.0.)  GO TO 200
   61 CONTINUE
 1001 FORMAT(F4.0,5(1XF2.0),1XF12.0)
  200 CONTINUE
      CALL DATEIN( D,SEC)
      SV = D(1)
      SV1 = D(2)
      SV2 = D(3)
C  CONVERT UNITS IF NECESSARY
      IF( IFLG(1).EQ.0) GO TO 301
      DO 45 I=1,NZN
   45 RAINR(I)= RAINR(I) *CNVRTR(IFLG(1))
  301 CONTINUE
C  READ NEXT DATA CARD TO DETERMINE RATE
   14 GO TO(15,25), ISW
   15 DO 62 I=1,NZN
      READ (4,1001,END=21) DS,RANL(I )
      IF(DS(1).EQ.0.)  GO TO 300
   62 CONTINUE
      GO TO 300
   25 READ(4,1001,END=21)DS,RANL(1)
      DO 47 I=1,NZN
   47 RANL(I)= RANL(1) * RNF(I)
  300 CONTINUE
C  CHECK FOR END
      DO 16 I=1,6
      IF (DS(I) .NE. 0.) GO TO 17
 16   CONTINUE
      GO TO 20
 17   IF (DS(1) .EQ. 0.) DS(1) = SV
      IF (DS(2) .EQ. 0.) DS(2) = SV1
      IF (DS(3) .EQ. 0.) DS(3) = SV2
      CALL DATEIN (DS,SEC2)
      IF(SEC.EQ.SEC2) GO TO 22
C  CONVERT UNITS
      IF(IFLG(1).EQ.0) GO TO 201
      DO446 I=1,NZN
  446 RANL(I)= RANL(I)*CNVRTR(IFLG(1))
  201 CONTINUE
C  DETERMINE RATE
      DO 90 I=1,NZN
      RAINRT(I)= (RANL(I)- RAINR(I))/ (SEC2-SEC)
      IF(RAINRT(I) .GE. 0.) GO TO 90
      IF(RANL(I) .NE. 0.) CALL ERROR(3)
      RAINRT(I) = 0.
   90 CONTINUE
 175  SV = DS(1)
      SV1 = DS(2)
      SV2 = DS(3)
      DO 100 I=1,NZN
      IF(RRTP(I).NE.RAINRT(I)) GO TO 101
  100 CONTINUE
```

SCRAM Program Listing (Continued)

```
      GO TO 10
  101 CONTINUE
C  OUTPUT
      WRITE (6,1005) D,(RAINRT(I),I=1,NZN)
 1005 FORMAT(6F6.0,6E15.7/ (36X,6E15.7/))
C     ZTIME=ETIME/60.
C     PUNCH 501, ZTIME, RAINRT
C     ETIME= ETIME+ (SEC2-SEC)
C     ZTIME=ETIME/60.
C     PUNCH 501, ZTIME, RAINRT
C 501 FORMAT(F9.2,G9.3)
      WRITE(11) SEC,(RAINRT(I),I=1,NZN)
      KTR = KTR + 1
C  UPDATE TIME AND RAINFALL FOR NEXT CALCULATION
      DO 91 I=1,NZN
   91 ATP(I)= RAINRT(I)
 10   SEC = SEC2
      DO 19 I=1,6
 19   J(I) = DS(I)
      DO 92 I=1,NZN
   92 RAINR(I)= RANL(I)
      GO TO 14
 20   REWIND 11
      GO TO 10
 21   REWIND 11
      IF (KTR .NE. 0) GO TO 50
C  CHECK FOR NEW STORM (GAUGE READING BACK TO ZERO)
   22 DO 222 I=1,NZN
      IF(RANL(I).NE.0.) CALL ERROR(3)
      RAINRT(I)=0.
  222 CONTINUE
      GO TO 175
C  DAY OR NITE EPA DATA CARDS
C  (ONLY DAY FUNCTIONING NOW)
 30   IF(TYPE.NE.DAYS .AND. TYPE.NE.ANIT) CALL ERROR(3)
      WRITE(6,1006)
 1006 FORMAT('1 EPA ENVIRONMENTAL DATA'//  '  YEAR MONTH  DAY  HOUR  MIN
     1UTE SECOND  WIND V        TEMPERATURE    SOLAR RADIATION  ATMOS PR
     2ES   RELATIVE HUMIDITY'//)
      READ(4,1010) (EMF(I),I=1,NZN)
   32 CONTINUE
      IF(EMF(1).EQ.-1.) GO TO 52
      READ (4,1002,END=41) D,WIND(1),TEMP(1),RAD(1),PRES(1),HUM(1)
      DO 66 I=2,NZN
      WIND(I)= WIND(1) *EMF(I)
      TEMP(I)= TEMP(1) * EMF(I)
      RAD (I)= RAD (1) * EMF(I)
      PRES(I)= PRES(1) * EMF(I)
      HUM (I)=  HUM(1) * EMF(I)
   66 CONTINUE
      GO TO 54
   52 DO 64 I=1,NZN
      READ (4,1002,END=41) D,WIND(I),TEMP(I),RAD(I),PRES(I),HUM(I)
      IF(D(1). EQ.0.)GO TO 54
```

SCRAM Program Listing (Continued)

```
   64 CONTINUE
 1004 FORMAT(F4.0,5(1XF2.0),1X5F12.0)
C  CHECK FOR END
   54 DO 34 I=1,6
      IF(D(I) .NE. 0.) GO TO 35
 34   CONTINUE
      GO TO 40
 35   IF (D(1) .EQ. 0.) D(1) = SV
      IF (D(2) .EQ. 0.) D(2) = SV1
      IF (D(3) .EQ. 0.) D(3) = SV2
C  CONVERT UNITS AS NECESSARY
      DO 65 I=1,NZN
      IF(IFLG(1) .NE. 0) WIND(I) = WIND(I)*CNVRTW(IFLG(1))
      IF (IFLG(2) .NE. 0) TEMP(I) = 0.5555556*(TEMP(I)-32.)
      IF(IFLG(3) .NE. 0) RAD(I) = RAD(I)*CNVRTS(IFLG(3))
      IF (IFLG(4) .NE. 0) PRES(I) = PRES(I)*CNVRTP(IFLG(4))
      IF (IFLG(5) .NE. 0) HUM(I) = HUM(I)/100.
      WRITE (6,1005) D, WIND(I),TEMP(I),RAD(I),PRES(I),HUM(I)
   65 CONTINUE
      CALL DATEIN (D,SEC)
      SV = D(1)
      SV1 = D(2)
      SV2 = D(3)
      KTEPA = KTEPA + 1
      WRITE(12) SEC,(WIND(I),TEMP(I),RAD(I),PRES(I),HUM(I), I=1,NZN)
      GO TO 32
 40   REWIND 12
      GO TO 10
 41   REWIND 12
 50   CONTINUE
      WRITE(6,1003) KTR,KTEPA
 1003 FORMAT('0',I10,' RAIN CARDS AND ',I5,' EPA DATA CARDS READ.'//)
      RETURN
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE SETUP
C
      DIMENSION D(2),T(2)
      DIMENSION CARD(20)
C
      CALL TODAY(D)
      CALL TIMEOD(T)
      WRITE(6,4)D,T
8     WRITE (6,1)
      WRITE(6,2)
      WRITE(6,3)
      WRITE(6,4)D,T
      WRITE (6,1)
      WRITE(6,2)
      WRITE(6,3)
      WRITE (6,1010)
10    READ(4,1005,END=20) CARD
      WRITE(6,1006) CARD
      GO TO 10
20    REWIND 4
      WRITE(6,1011)
30    READ(5,1005,END=40) CARD
      WRITE(6,1006) CARD
      GO TO 30
40    REWIND 5
      RETURN
4     FORMAT('1'/15X'DATE:',2A4,65X'TIME:',2A4)
1     FORMAT(     //56X17('E'),/51X27('E')/47X34('E')/44X40('E')/
     141X35('E'),1X,9('S')/
     2 39X,32('E'), 1X,10('S'), 1X, 5('L')/
     3 37X,30('E'), 1X,12('S'), 1X,10('L')/
     4 36X,29('E'),1 X,13('S'), 1X,12('L')/
     5 34X,29('E'), 1X,14('S'), 1X,15('L')/
     6 33X,29('E'), 1X,15('S'), 1X,16('L')/
     7 32X,29('E'), 1X,15('S'), 1X,18('L')/
     8 31X,29('E'), 1X,16('S'), 1X,19('L')/
     9 30X,30('E'), 1X,15('S'), 1X,21('L')/
     1 29X,30('E'), 1X,16('S'), 1X,22('L')/
     2 29X,29('E'), 1X,16('S'), 1X,23('L')/
     3 28X,30('E'), 1X,16('S'), 1X,24('L')/
     428X13('E'),9X 7('E'),1X4('S'),4X 8('S'),1X3('L'),3X20('L')/
     527X14('E'),9X 7('E'),1X3('S'),6X 7('S'),1X3('L'),3X20('L')/
     627X14('E'),3X12('E'),1X3('S'),3X 2('S'),3X5('S'),1X 4('L'),
     7 3X20('L')/
     826X15('E'),3X12('E'),1X3('S'),3X10('S'),1X4('L'),3X21('L')/
     926X15('E'),3X12('E'),1X3('S'),3X10('S'),1X4('L'),3X21('L')      )
2     FORMAT(
     126X15('E'),3X11('E'),1X5('S'),3X 8('S'),1X5('L'),3X21('L')/
     226X15('E'),5X 9('E'),1X6('S'),3X 7('S'),1X5('L'),3X21('L')/
     326X15('E'),5X 9('E'),1X7('S'),3X 6('S'),1X5('L'),3X21('L')/
     426X15('E'),3X10('E'),1X9('S'),3X 4('S'),1X6('L'),3X21('L')/
     526X15('E'),3X10('E'),1X 9('S'),3X 4('S'),1X6('L'),3X21('L')/
     626X15('E'),3X10('E'),1X4('S'),3X 2('S'),3X4('S'),1X 6('L'),
     7 3X21('L')/
```

SCRAM Program Listing (Continued)

```
     6 27X14('E'),9X 3('E'),1X6('S'),6X 4('S'),1X7('L'),9X14('L')/     00022920
     7 27X14('E'),9X 3('E'),1X7('S'),4X 5('S'),1X7('L'),9X14('L')/     00022930
     8 28X,25('E'), 1X,16('S'), 1X,30('L')/                           00022940
     9 28X,24('E'), 1X,16('S'), 1X,30('L')/                           00022950
     1 29X,23('E'), 1X,16('S'), 1X,30('L')/                           00022960
     2 29X,22('E'), 1X,16('S'), 1X,30('L')/                           00022970
     3 30X,21('E'), 1X,16('S'), 1X,29('L')/                           00022980
     4 31X,19('E'), 1X,16('S'), 1X,29('L')/                           00022990
     5 32X,18('E'), 1X,16('S'), 1X,28('L')                            00023000
3     FORMAT(                                                          00023010
     6 32X,17('E'), 1X,15('S'), 1X,28('L')/                           00023020
     7 34X,15('E'), 1X,14('S'), 1X,29('L')/                           00023030
     8 35X,13('E'), 1X,13('S'), 1X,30('L')/                           00023040
     9 37X,11('E'), 1X,10('S'), 1X,31('L')/                           00023050
     1 39X, 9('E'), 1X,11('S'), 1X,32('L')/                           00023060
     2 41X,           10('S'), 1X,35('L')/                            00023070
     3 43X,42('L')/46X36('L')/50X28('L')/55X16('L'))                  00023080
1010 FORMAT('1',40X'INPUT SEQUENTIAL DATA CARDS'//)                   00023090
1005 FORMAT(20A4)                                                     00023100
1006 FORMAT(15X20A4)                                                  00023110
1011 FORMAT('1',40X'INPUT NAMELIST DATA CARDS'//)                     00023120
     END                                                              00023130
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE SIMPSN (SUM,IS,NZ)
C
      COMMON /ADDATA/ C(27,20), S(27,20), KNT, SSS(27,20)
     1      ,DC(27), VEL(27), THETJ(27), B(27),KDES(27,20),CMAXUM(27,20),
     2      THETA,NMAX, H, KTIME,II, A, DENOM,DENAM,INDEX(20),INDEX1(20),
     3      ANT, AX, IISAVE, IGOR, NVAL(20),DESNRO, XPONT,KLEW1(20),DVST,
     4      THETAT, SUMC(27), SUMS(27),CUMAO, CUMDS,PTOT(20) ,C1(27,20)
C
C  INTEGRATES S/CO AND C/CO FOR OUTPUT VALUES FROM SUBROUTINE RUNGE
C
C     SUMCL=0
      SUMC(NZ) = 0
      SUMS(NZ) = 0
   40 DO 13 NODD=2,IS
      IF(NODD-IS) 50,13,13
   50 SUMS(NZ)  = SUMS(NZ) + 2.*S(NODD,NZ)
      SUMC(NZ) = SUMC(NZ) + 2.*C1(NODD,NZ)*THETJ(NODD)
C
C     SUMCL= SUMCL+2.*CLGRID(NODD)*THETA(NODD,NZ)
C
   13 CONTINUE
      SUMS(NZ) = H/2.*(SUMS(NZ)+S(1,NZ)+S(IS,NZ))
      SUMC(NZ) = H/2.*(SUMC(NZ)+C1(1,NZ)*THETJ(1) + C1(IS,NZ)*THETJ(IS))
C
C     SUMCL= (SUMCL+CLORID(1)*THETA(1,NZ)+CLORID(II)*THETA(II,NZ))*H/2.
C
      SUM=SUMS(NZ) + SUMC(NZ)
      RETURN
      END
```

SCRAM Program Listing (Continued)

```
      FUNCTION SOLAR (A,T)
C
      REAL*8 T
C
      DIMENSION D(3)
C
      COMMON /CONST/ CON(50)
C
      CALL DATOUT (T,D,1)
      AMO = AMOD(D(1),100.) + 9.
      FACT = COS((CON(20) - (23.45*SIN(6.283185*AMO/12)))*.017453)
      SOLAR = CON(21)*FACT*(1.-.09*A)
      RETURN
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE VOLT
C
C
C     SUBROUTINE TO PREDICT PESTICIDE LOSS DUE TO THE PESTICIDES'
C     VOLATILE PROPERTIES
C
      COMMON /EVAPIN/ ELE2,WVL2,TEM2
      COMMON /TIMES/ TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,
     1      EPATM, PAINT(3), PROGDT(3), PESTM
      REAL*8 TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,EPATM,PESTM
      COMMON /WATERD/ NZN, RAINR, THETA(27,20),THETN(27,20)
      COMMON /SEDATA/SUB(10,20)
C
      COMMON /VOLTG/ ENG,ALFA,DV(27,20),DIST(27,20),IV1,PPB(27,20),
     1                DVS(27,20),P2
C
      DIMENSION XRYS(27,20),XRYI(27,20),IC(20),CZ(20),KFLAG(20),TP(27),
     1     F1(27,20),F2(27,20),FF(27,20)
C
C
C
C
C  (27,20)
C  (NL,NZ) =  NL--LAYER
C             NZ--ZONE
C
C
C  ENG= NANOGRAMS OF PESTICIDE APPLIED (INPUT)
C  ALFA= APPLICATION RATE OF PESTICIDE (LBS/ACRE) (INPUT)
C  DIST(27,20)= DISTRIBUTION OF PESTICIDE (INPUT)
C  DV(27,20)= DIFFUSION COEFFICIENTS (INPUT)
C  DVS(27,20)= DIFFUSION COEFFICIENTS (=DV IF DV NE 0.; OTHERWISE CALC)
C  VTIME= PREVIOUS ELAPSED TIME SINCE PESTM (DATE OF PEST. APPLICATION)
C  VTI  = PRESENTS ELAPSED TIME SINCE PESTM (DATE OF PEST. APPLICATION)
C  VT= DT,TIME INCREMENT
C  IV1= FLAG FOR 1ST TIME THRU VOLT
C  P2= AMT. OF PESTICIDE REMAINING W/R TOTAL
C  BD=SUB(6,I)=BULK DENSITY OF SOIL (G/CC)
C  NL=SUB(8,I)= NO. OF LAYERS IN ZONE(I)
C  DN=SUB(9,I)= LAYER THICKNESS(CM)
C  TEMP=TEM2= TEMPERATURE IN 0-1 CM (DEG. C)
C  IC(NZ)= LAYER NO. FOR THIS ZONE, ALL ABOVE IT HAVE EQUAL CONC.
C  PPB(27,20)= CONC. OF PESTICIDE IN PARTS/BILLION
C              (NEITHER IN SOLN. NOR ADSORBED)
C  KFLAG(NZ)=1 , CHANGE CZ(NZ) NEXT TIME AROUND
C
      IF(TOLD.LT.PESTM) RETURN
C
C  CHECK FOR 1ST TIME THRU
      IF(IV1.NE.0) GO TO 90
      IV1=-1
C
C  SET UP FOR 1ST TIME THRU
      VTIME= 0.0
```

SCRAM Program Listing (Continued)

```
      T2= VTIME
      TOTP= ALFA* ENG
      PTOTAL=0.
      TEMPI=TEM2
      DO 113 J=1,NZN
      BD= SUB(6,J)
      NL= SUB(8,J)-1
      DO 13 I=1,NL
      XRYS(I,J)= DIST(I,J) * TOTP/NZN
      PTOTAL=PTOTAL+ XRYS(I,J)
      XRYI(I,J)= XRYS(I,J)
   13 PPB(I,J)=XRYI(I,J)/BD
      KFLAG(J)=0
      IC(J)=1
      C2(J)=XRYI(1,J)
      F2(I,J )= 0.0
  113 CONTINUE
      P2=PTOTAL/TOTP * 100.
C
C  PRINT INITIAL VALUES
      WRITE(6,2000)  ENG,ALFA
 2000 FORMAT('1', 'INITIAL CONDITION OUTPUT' //
     1  1X,G12.4,2X,'NANOGRAMS OF PESTICIDE APPLIED' /
     2  1X,G12.4,2X,'APPLICATION RATE(LBS/ACRE)'  //)
      CALL VPRNT
      IV1=1
C
C
   90 VTT= TOLD-PESTN
C  CHECK TO SEE IF ELAPSED TIME SINCE LAST CALC. IS GE 1 HOUR
      IF(VTT-VTIME .LT.3600.)  RETURN
C
C  PROCEED WITH CALCULATION
      T1= T2
      T2= VTT
      VTIME=VTT
      VT=T2-T1
      PTOTAL=0.
C
      DO 501 JJ=1,NZN
      NL=SUB(8,JJ)-1
      BD=SUB(6,JJ)
      NLL=NL-1
      DX=SUB(9,JJ)
C
      DO 5011 I=1,NL
      F1(I,JJ)= F2(I,JJ)
      TP(I)= TEMPI  - (I-1) *0.5
      IF(TEMPI.LT.35.)  TP(I)= TEMPI
      IF(DV(I,JJ).EQ.0.)GO TO 5012
      DVS(I,JJ)= DV(I,JJ)
      GO TO 5011
 5012 TH1= THETN(I+1,JJ) *100.
      TH2= TH1*TH1
```

SCRAM Program Listing (Continued)

```
      TH3=TH2*TH1
      TH4=TH3*TH1
      TH5= TH4*TH1
      TH6=TH5*TH1
      TEMP= TP(I)
      TEMP2= TEMP*TEMP
      TEMP3= TEMP2*TEMP
      DVS(I,JJ)= 10.** ( -0.313-1.051 * TH1 + 0.054 * TH2 -8.494E-4 *TH3
     1 -8.997 * BD + 6.021E-5 * TH1 * TEMP2 - 7.359E-7 * TH1* TEMP3
     2  +1.483E-6 * TH4 * TEMP -8.863E-8* TH5 * TEMP + 1.362E-9 * TH6*
     3  TEMP + 1.588 * TH1 * BD -0.108 * TH2 * BD + 2.880E-3 * TH3 * BD
     4  - 2.560E-5 * TH4 * BD + 4.664E-2 * TEMP * BD - 3.013E-3 * TH1 *
     5   TEMP * BD  )
 5011 CONTINUE
C
      ICC=  IC(JJ)
C
      IF(KFLAG(JJ).NE.1) GO TO 30
      KFLAG(JJ)=0
      GO TO 200
   30 CONTINUE
C
      Z1= SQRT(DVS(ICC,JJ)             / 3.1415927)
      F2(ICC,JJ)= Z1* CZ(JJ)/ SQRT(T2)
      DEL= 2.*F2(ICC,JJ)*T2-2.*F1(ICC,JJ) * T1
C  ALLOCATE LOSSES TO IC(JJ) LAYERS
C
      DO 25 I1= 1,ICC
   25 XRYS(I1,JJ)= XRYS(I1,JJ)-DEL/ ICC
C
   25 CONTINUE
C
      DO 142 J=1,NLL
  142 FF(J,JJ)= DVS(J,JJ) * (XRYS(J,JJ)- XRYS(J+1,JJ)) / DX
      DO 442 J=1,NLL
      XRYS(J,JJ)= XRYS(J,JJ) -FF(J,JJ) * VT
      XRYS(J+1,JJ) = XRYS(J+1,JJ) + FF(J,JJ) *VT
  442 CONTINUE
C
      DO 52 I=1,NL
      IF(XRYI(I,JJ). NE. 0.)  GO TO 31
      P1=0.
      GO TO 32
   31 P1= XRYS(I,JJ)/XRYI(I,JJ)*100.
   32 PTOTAL= PTOTAL + XRYS(I,JJ)
      PPB(I,JJ)= XRYS(I,JJ)/BD
   52 CONTINUE
C
      IF(ICC   .EQ.NL) GO TO  501
C  CHECK TO SEE IF TIME TO CHANGE CZ(JJ)
C
      IF(XRYS(ICC   ,JJ).GE.XRYI(ICC   +1 ,JJ))GO TO 501
C  SET  KFLAG & MAKE ADJUSTMENT NEXT TIME WHEN WE KNOW WHAT VT TO USE
      KFLAG(JJ)=1
```

SCRAM Program Listing (Continued)

```
      GO TO 501
  200 CONTINUE
C
C   READY TO CHANGE CZ(JJ)--MAKE ADJUSTMENTS TO XRYS(((I=1,ICC),JJ)
C
C  CSAVE IS LAST VALUE OF XRYS(IC(JJ),JJ)  <  XRYI(IC(JJ),JJ)
C
      CSAVE = XRYS(ICC,JJ)
      F1(ICC,JJ)= XRYI(ICC+1,JJ) *F2(ICC,JJ) /XRYI(ICC,JJ)
      IC(JJ)=IC(JJ)+1
      ICC=IC(JJ)
      CZ(JJ)= XRYI(ICC,JJ)
      Z1= SQRT(OVS(ICC,JJ) / 3.1415927      )
      F2(ICC,JJ)= Z1 *CZ(JJ)/ SQRT(T2)
      DDL         = 2.*F2(ICC,JJ)* T2 -2.* F1(ICC-1,JJ)* T1
      DDLP         = XRYI(ICC,JJ) - XRYS(ICC-1,JJ)
      DO 35 I=1,ICC
      XRYS(I,JJ)= CSAVE - (DDL -DDLP) /ICC
   35 CONTINUE
      GO TO 29
C
  501 CONTINUE
C
      P2= PTOTAL/TOTP * 100.
C  FINISHED, PRINT BEFORE RETURNING
C
      WRITE(6,8000)
 8000 FORMAT('1')
      CALL VPRNT
C
      RETURN
      END
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE VPRNT
C
C  SUBROUTINE TO PRINT VALUES GENERATED BY SR VOLT
C
      COMMON /SEDATA/SUB(10,20)
C
      COMMON /TIMES/ TOLD.TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,
     1     EPATM, PRINT(3), PROGDT(3), PESTM
      REAL*8 TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,EPATM,PESTM
C
      COMMON /VOLTD/ ENG,ALFA,DV(27,20),DIST(27,20),IV1,PPB(27,20),
     1               DVS(27,20),P2
C
      COMMON /WATERD/ NZN
      DIMENSION D(3)
      REAL*8 VLAP
C
C  NTH =MAX VALUES OF THETA = (NO. OF LAYERS) = SUB(8,I)
C
      IF(TOLD.LT.PESTM) RETURN
      VLAP=TOLD-PESTM
      WRITE(6,2000)
 2000 FORMAT(    5X,'VOLITALIZATION OUTPUT' )
      IF(IV1.EQ.-1) GO TO 10
      CALL DATOUT(TNEW,D,0)
      WRITE(6,2001)   VLAP
 2001 FORMAT(5X,'ELAPSED TIME: ' ,G12.4,'SEC'  )
   10 WRITE(6,1000)
 1000 FORMAT('0', 50X'ZONE DEPTH PROFILE')
      NTH=1
      TH= 1.0
      DO 40  I=1,NZN
 40   TH  = MAX1(TH,SUB(8,I) )
      NTH=TH -1
      ISW=1
      NA=1
      NB=NZN
      IF(NB.LE.10) GO TO 50
      NB=10
 50   CONTINUE
      WRITE (6,310)
  310 FORMAT('0',55X,'ZONE #'  )
      WRITE (6,320) (I1,I1=NA,NB)
  320 FORMAT(  ' PROFILE',3X, 10(5X,I2,4X) )
      WRITE(6,321)
  321 FORMAT(' VOLITALIZED PESTICIDE (PPB) ')
      DO 340 I2=1,NTH
  340 WRITE (6,330)  I2,((  PPB(I2,I1), I1=NA,NB)   )
  330 FORMAT(3X, I2,4X, 10F11.3  )
      IF(IV1.EQ.-1) GO TO 52
      WRITE(6,431)
  431 FORMAT('0DIFFUSION COEFFICIENTS')
      DO 440 I2=1,NTH
  440 WRITE(6,33 ) I2,((DVS(I2,I1),I1=NA,NB))
```

SCRAM Program Listing (Continued)

```
33 FORMAT(3X, I2,4X, 10G11.3  )                                        00026050
   GO TO (51,52), ISW                                                  00026060
51 IF(NZN.LE.10) GO TO 52                                              00026070
   NA= NB+1                                                            00026080
   NB= NZN                                                             00026090
   ISW = 2                                                             00026100
   GO TO 50                                                            00026110
52 CONTINUE                                                            00026120
   WRITE(6,70) P2                                                      00026130
70 FORMAT('0 % PESTICIDE REMAINING W/R TOTAL', F10.3)                  00026140
   RETURN                                                              00026150
   END                                                                 00026160
```

SCRAM Program Listing (Continued)

```
      SUBROUTINE WATER(NZ,NEWFLG)
C
C  SUBROUTINE TO PREDICT THE AMT. OF RUNOFF ON THE WATERSHED DURING
C    EACH EVENT, AND THE MOVEMENT OF WATER INTO THE SOIL PROFILE DURING
C    AND AFTER AN EVENT.
C
      COMMON /SEDATA/SUB(10,20),ADJLI(21),ADJLO(20),RNF(4,20),INF(4,20)
C
      COMMON /WATERQ/ NZN, RAINR(20),  THETA(27,20),THETN(27,20),CUMRO
     &      ,CUMFLT,DHTAB(50,4,10),NUMDH(10),RINF(20),CIT(20),VELC(27,20)
     &      ,Q(27,20),SUMRN,WATROT,SUMIN,ROR
C
      COMMON /TIMES/ TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,
     &      EPATM, PRINT(3), PROGDT(3)
      REAL*8 TOLD,TNEW,DT,DTOLD,TOUT,TSTRT,TSTOP,TRAIN,PIN,EPATM
C
      DIMENSION  H(30),                                 HH(27), WORK(27),
     &           RHS(27), CAP(27), COEF(77)
C
C  NZN= NO.OF ZONES
C  RAINR= RAINFALL RATE(CM/SEC)
C  THETA= WATER PROFILE AT PREVIOUS CYCLE
C  THETN= NEW WATER PROFILE
C  CUMRO= CUMULATIVE RUNOFF AT BOTTOM (ZONE # 21)
C  CUMFLT= CUMULATIVE INFILTRATION LOSS
C  DHTAB= THETA,DIFFUSIVITY, PRESSURE HEAD TABLES
C  NUMDH= NO. OF ENTRIES IN CORRESPONDING DHTAB
C  RINF= INFILTRATION RATE
C  VELC= INFILTRATION VELOCITY
C  Q= INFILTRATION FLUX
C
C    NZ = ZONE NUMBER (SUPPLIED THRU CALL )
C    NS = SOIL TYPE   (= SUB(1,NZ) IN COMMON /SEDATA/ )
C   G =LAYER THICKNESS =SUB(9,NZ)
C  NDH= # OF VALUES OF DHTAB, MAX=50
C
      NS=SUB(1,NZ)
      NDH = NUMDH(NS)
      NEND1 = SUB(8,NZ)
      G=SUB(9,NZ)
C
      TH1= THETA(1,NZ)
C
C  HH(N) = PRESSURE HEAD AAT LAYER N
C  THETA(N,NZ) = MOISTURE (PERCENT)AT LAYER N
C    WHERE N=1 IS THE RAIN LAYER, N=2 IS THE TOP SOIL LAYER
C      NZ IS THE  ZONE NUMBER
C
C
C  NEND(NZ)=NEND1 = NUMBER OF SOIL LAYERS
C
      NENDP =NEND1-1
C
C     COMPUTE PRESSURE HEAD VALUES (HM) FROM TABLE FOR THETA
```

```
C           VALUES VIA INTERPOLATION.  ITABLE COMPUTES CORRECT ENTRY
C           POINTS INTO TABLE FOR INTERPOLATION
C
C
C
C   THETA(I,NZ) IS OLD VALUES OF THETA
C   THETN(I,NZ) IS NEW VALUES OF THETA
C   W(N) IS THE WORKING ARRAY AND IS = THETA(I,NZ) AT BEGINNING OF ROUTIN
C
      HH(1) = 0.
      W(1)= THETA(1,NZ)
      DO 50 N=2,NEND1
      W(N) = THETA(N,NZ)
      I= ITABLE(W(N)         ,DHTAB(1,1,NS),NDH-1)
      HH(N)= DHTAB(I,3,NS) + (W(N)         - DHTAB(I,1,NS)) /
     1  (DHTAB(I+1,1,NS) - DHTAB(I,1,NS)) *(DHTAB(I+1,3,NS)
     2 - DHTAB(I,3,NS))
   50 CONTINUE
      THETA(NEND1+1,NZ)= THETA(NEND1,NZ)
      W(NEND1+1)  = THETA(NEND1,NZ)
C
C     SETS BOUNDARY CONDITION AT EQUAL MOISTURE CONTENT LAYER
C
      HH(NEND1+1) = HH(NEND1)
C
C     DOES CALCULATED INFILTRATION EXCEED RAINFALL RATE?
C
   22 CONTINUE
C
C     DOES RAINFALL EXCEED THETA SATURATION?
C
  25  THETA(1,NZ) = TH1 + RAINR(NZ)* DT/G
      W(2) = THETA(2,NZ) + THETA(1,NZ)
C
C   DOES W(2) EXCEED THETA  SAT?
C
      IF(W(2)- DHTAB(NDH,1,NS)) 27,27,30
  27  AINF(NZ) = THETA(1,NZ)*G/DT
      RUNOF=0.
      GO TO 60
  30  RUNOF = W(2) - DHTAB(NDH,1,NS)
      AINF(NZ) = (THETA(1,NZ) - RUNOF)*G/DT
      W(2)         =DHTAB(NDH,1,NS)
   60 I= ITABLE(W(2)         ,DHTAB(1,1,NS),NDH-1)
C
C     DETERMINE NEW HH(2)
C
      HH(2)= DHTAB(I,3,NS) + (W(2)          -DHTAB(I,1,NS))
     1 /(DHTAB(I+1,1,NS) -DHTAB(I,1,NS))*(DHTAB(I+1,3,NS)-DHTAB(I,3,NS))
C
C     SET UPPER BOUNDARY CONDITION
C
   62 W(1)=W(2)
      HH(1) = HH(2)
```

```
C CALCULATE CONDUCTIVITY FOR EACHDEPTH LEVEL
C  WORK(I) = K-(I) = K+(I-1)
C     J=ITABLE(W(1)         ,DHTAB(1,1,NS),NDM)
C     C1=DHTAB(J,4,NS) +(W(1)         -DHTAB(J,1,NS))/(DHTAB(J+1,1,NS)
C    1    -DHTAB(J,1,NS))*(DHTAB(J+1,4,NS) - DHTAB(J,4,NS))
      C1 = 0.
      DO 200 N=1,NEND1
      THEST = (W(N)         +W(N+1)        )*.5
      I=ITABLE(THEST,DHTAB(1,1,NS),NDM-1)
      CAP(N)=(DHTAB(I+1,1,NS)- DHTAB(I,1,NS))/(DHTAB(I+1,3,NS)-
     1  DHTAB(I,3,NS)   )
   65 I = ITABLE(W(N+1)         ,DHTAB(1,1,NS),NDM-1)
      CX= DHTAB(I,4,NS)+ (W(N+1)        -DHTAB(I,1,NS))/(DHTAB(I+1,1,NS)
     1    -DHTAB(I,1,NS)) *(DHTAB(I+1,4,NS) -DHTAB(I,4,NS))
      WORK(N)= DHTAB(I,2,NS) *CAP(N)
      IF(ABS(W(N)         -W(N+1)         )-1.E-6 ) 90,90,70
   70 DIF = (C1-CX)/(HH(N) - HH(N+1))
      WORK(N) = DIF
   90 J = I
      C1 = CX
      IF(N.EQ.1) CON1= DIF
200   CONTINUE
      WORK(NEND1) =0.
      WORK(1) = 0.
C SET UP COEFFICIENT MATRIX AND RHS
  105 M = 3
      DTDXS= DT/(G*G)
      C1= DTDXS*WORK(1)/CAP(1)
      CX = DTDXS*WORK(2)/CAP(1)
      C3 = C1+CX
C
C     MATRIX ELEMENT TOO LARGE
C
      IF (ABS(C3) .GE. 2. .AND. NEWFLG .EQ. 0) GO TO 810
      COEF(1) = 2.+C3
      COEF(2) = -CX
      RHS(2) = (2.-C3)*HH(2) + CX*HH(3)
      DO 110 N = 2,NENDP
      C1 = DTDXS*WORK(N)/CAP(N)
      CX = DTDXS*WORK(N+1)/CAP(N)
      C3 = C1 + CX
      IF (ABS(C3) .GE. 2. .AND. NEWFLG .EQ. 0) GO TO 810
      COEF (M) = -C1
      COEF(M+1) = 2. + C3
      COEF(M+2) = -CX
      RHS(N+1) = C1*HH(N) + (2.-C3)*HH(N+1) + CX*HH(N+2)
     1  + 2.*G      * (C1-CX)
      M = M + 3
  110 CONTINUE
C SOLVE - NEW HH WILL BE IN RHS
C
C     INVERT TRIDIAGONAL MATRIX
C
      CALL GELB(RHS(2),COEF   , NENDP, 1,1,1, 1.E-5, IER)
      IF (IER) 400,115,400
  115 CONTINUE
C
C     COMPUTE NEW THETAS AND CUMUNICATIVE INFILTRATION
C
      DO 410 N= 2,NEND1
      TERM = (RHS(N) - HH(N))*CAP(N-1)
      THETN(N,NZ) = W(N) + TERM
  410 CONTINUE
      THETN(1,NZ)= RUNOF
  420 CIT(NZ)= CIT(NZ) + RINF(NZ) *DT
C  ACCUMULATE WATER LOSS DUE TO INFILTRATION
      CUMFLT = CUMFLT + (THETN(NEND1,NZ)-W(NEND1))*G*SUB(2,NZ)/1000.
      SUM1 = 0.
      SUM2 = 0.
      DO 425 I=2,NEND1
      SUM1 = SUM1 + THETN(I,NZ)
      SUM2 = SUM2 + W(I)
  425 CONTINUE
      DIF = SUM1 - SUM2
      THETN(2,NZ) = THETN(2,NZ) - DIF
      THETN(NEND1,NZ) = W(NEND1)
C
C  CALCULATE INFILTRATION VELOCITY-VELC
C  CALCULATE INFILTRATION FLUX-Q
C
      VELC(1,NZ) = RINF(NZ)
      Q(1,NZ) = RINF(NZ)*DT
      DO 440 I=2,NENDP
      VELC(I,NZ) = ((HH(I) + RHS(I) + 2.*G - HH(I+1) - RHS(I+1))/
     1      (2.*G))*WORK(I)
 440  Q(I,NZ) = THETA(I,NZ) + Q(I-1,NZ) - THETN(I,NZ)
      VELC(NEND1,NZ) = (THETN(NEND1,NZ) - W(NEND1))*G/DT
      Q(NEND1,NZ) = Q(NENDP,NZ)
      GO TO 900
  400 WRITE(6,9000) IER
      GO TO 115
  810 DT  =1.9*DT  /ABS(C3)
      GO TO 22
  900 CONTINUE
      NEWFLG = 1
      RETURN
9000  FORMAT ('OGELB ROUTINE ERROR CODE = ',I2)
      END
```

APPENDIX C
SCRAM SAMPLE OUTPUT

Sample SCRAM Input/Output Listing

```
                                       INPUT SEQUENTIAL DATA CARDS

RAIN
   10
  1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
 1973 06 28 03 35             0.0             0          0.0
 1973 06 28 03 40             0.41            1         29.95
 1973 06 28 16 30             0.0             0          0.0
 1973 06 28 16 35             0.25            1         84.27
 1973 06 28 16 40             0.30            6       2600.72
 1973 06 28 16 45             0.34           11        886.04
 1973 06 28 16 50             0.38           16        103.07
 1973 06 28 16 51             0.0            17         38.90
 1973 37 08 16 52             0.0             0          0.0
 1973 07 08 16 55             0.16            3       1760.52
 1973 07 08 17 00             0.34            8       4 62.07
 1973 07 08 17 02             0.41           10       3371.68
 1973 07 08 17 05             0.52           13       2464.52
 1973 07 08 17 10             0.68           18       1313.46
 1973 07 08 17 15             0.80           23       1647.32
 1973 07 08 17 20             0.91           28       5349.21
 1973 07 08 17 25             1.03           33       4184.10
 1973 07 08 17 30             1.14           38       3185.24
 1973 07 08 17 35             1.26           43       2229.42
 1973 07 08 17 40             1.37           48         27.14
 1973 07 08 17 45             1.42           53         26.33
 1973 07 08 17 55             1.49           63         24.74
 1973 07 08 18 10             1.60           78         22.44
 1973 07 08 18 20             1.68           88         20.97
 1973 07 08 18 23             1.73           91         16.87
 1973 07 16 20 35             0.0             0          0.0
 1973 07 16 20 40             0.09            0          0.0
 1973 07 16 20 45             0.23            0          0.0
 1973 07 16 20 48             0.33            0          0.0
 1973 07 16 20 50             0.39            0          0.0
 1973 07 16 20 53             0.49            0          0.0
 1973 07 16 20 55             0.56            0          0.0
 1973 07 16 20 58             0.66            0          0.0
 1973 07 16 21 00             0.68            0          0.0
 1973 07 16 21 05             0.73            0          0.0
 1973 07 16 21 10             0.79            0          0.0
 1973 07 16 21 15             0.84            0          0.0
 1973 07 16 21 20             0.89            0          0.0
 1973 07 17 10 41             0.0             0          0.0
 1973 07 17 10 46             0.22            0          0.0
 1973 07 17 10 51             0.44            0          0.0
 1973 07 17 10 56             0.61            1         95.31
 1973 07 17 11 01             0.63            6       3 35.31
 1973 07 17 11 06             0.65           11       1648.12
 1973 07 17 11 11             0.68           16        720.39
 1973 07 17 11 16             0.70           21        191.26
 1973 07 17 11 21             0.72           26          9.71
 1973 07 17 11 26             0.74           31          6.46
 1973 07 17 11 31             0.76            0          0.0
 1973 07 25 20 10             0.0             0          0.0
 1973 07 25 21 00             0.13            0          0.0
 1973 07 25 21 20             0.18            0          0.0
 1973 07 25 21 30             0.25            0          0.0
 1973 07 25 21 50             0.32            0          0.0
 1973 07 25 22 10             0.38            0          0.0
 1973 07 30 19 15             0.0             0          0.0
```

Sample SCRAM Input/Output Listing - Continued

```
1973 07 30 19 10          0.13          0        0.0
1973 07 30 19 15          0.23          0        0.0
1973 07 30 19 20          0.35          0        0.0
1973 07 30 19 25          1.31          5    14932.17
1973 07 30 19 30          2.29         10    22860.34
1973 07 30 19 35          2.52         15    18552.58
1973 07 30 19 40          2.67         20     9359.71
1973 07 30 19 45          2.79         25     3691.77
1973 08 01 17 30          0.0           5        0.0

DAYS
  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.
1973 01 01             2.01          83.35     5.      1.      .6
1973 07 01             1.96          80.       5.      1.      .65
1973 07 08             1.96          77.26     5.      1.      .62
1973 07 17             1.72          70.62     5.      1.      .60
1973 07 30             1.57          81.46     5.      1.      .6
1973 09 01             5.7           75.4      9.5     1.      .75
1979 01 01             2.01          83.35     5.      1.      .6
```

Sample SCRAM Input/Output Listing - Continued

```
                              INPUT NAMELIST DATA CARDS

&PESTI
PLOTNM= 'P-01'
PESTNM='DIPHENAMID'
STARTM=73,07,08,16,52
ENDTM=73,07,16,21,30
CROPDT= 0,73,6,13,73,11,1,73,9,12,
PESDAT=5*0., 73, 6, 13,
THETA=
0.,.500,.061,.062,.063,.064,.065,.066,.067,.068,.069, 4*.07, 12*0.,
0.,.500,.061,.062,.063,.064,.065,.066,.067,.068,.069, 4*.07, 12*0.,
0.,.500,.061,.062,.063,.064,.065,.066,.067,.068,.069, 4*.07, 12*0.,
0.,.500,.061,.062,.063,.064,.065,.066,.067,.068,.069, 4*.07, 12*0.,
0.,.500,.061,.062,.063,.064,.065,.066,.067,.068,.069, 4*.07, 12*0.,
0.,.500,.061,.062,.063,.064,.065,.066,.067,.068,.069, 4*.07, 12*0.,
0.,.500,.061,.062,.063,.064,.065,.066,.067,.068,.069, 4*.07, 12*0.,
0.,.500,.061,.062,.063,.064,.065,.066,.067,.068,.069, 4*.07, 12*0.,
0.,.500,.061,.062,.063,.064,.065,.066,.067,.068,.069, 4*.07, 12*0.,
0.,.500,.061,.062,.063,.064,.065,.066,.067,.068,.069, 4*.07, 12*0.,
DHARAY=2.23,
.05,.07,.09,.11,.13,.15,.17,.19,.21,.23,.25,.27,.29,.31,.33,.35,.37,
.39,.41,.43,.45,.47,.49,
.60E-5,.86E-5,.13E-4,.23E-4,.40E-4,.68E-4,.12E-3,.18E-3,.28E-3,.40E-3,
.56E-3,.80E-3,.12E-2,.17E-2,.24E-2,.32E-2,.44E-2,.60E-2,.80E-2,.11E-1,
.15E-1,.19E-1,.26E-1,
-.60E6, -.90E5,-.40E5,-.10E5,-.70E4,-.47E4,-.20E4,-.10E4,-.80E3,-.68E3,
-.57E3,-.45E3,-.33E3,-.22E3,-.10E3,-.90E2,-.77E2,-.60E2,-.50E2,-.40E2,
-.20E2,-.10E2,0.0
FUNOFF=
21, 1, 6*0,
 1, 1, 6*0,
10,1, 10, 2, 4*0,
3, 1, 10, 7, 4*0,
4, 2, 10, 1, 4*0,
7, 2, 10, 1, 4*0,
 1, 1, 6*0,
1, 3, 10, 1, 4*0,
5, 1, 10, 4, 4*0,
8, 50, 10, 50, 4*0,
ZONES=
2, .042, 4, 87.5, 75.,        1.6, 3, 15, 1, 1500, 2, 1, 0, 0
2, 0.941, 3, 856.25, 99.97, 1.6, 3, 15, 1, 1500, 2, 1, 0, 0
1, 1.47, 4, 425, 187.5,       1.6, 3, 15, 1, 1500, 2, 1, 0, 0
1, .659, 3, 287.5, 156.25,  1.6, 3, 15, 1, 1500, 2, 1, 0, 0
1, .496, 3, 300, 106.25,      1.6, 3, 15, 1, 1500, 2, 1, 0, 0
1, 1.059, 2, 362.5, 175.,     1.6, 3, 15, 1, 1500, 2, 1, 0, 0
1, .545, 4, 325, 187.5,       1.6, 3, 15, 1, 1500, 2, 1, 0, 0
1, 0.42, 4, 225, 125,         1.6, 3, 15, 1, 1500, 2, 1, 0, 0
1, .61, 2, 112.5, 212.5,      1.6, 3, 15, 1, 1500, 2, 1, 0, 0
1, 0.428, 4, 225, 118.75,     1.6, 3, 15, 1, 1500, 2, 1, 0, 0
AK1=10*200., AK2=10*1.E-2, ST=10*24.,
CON(6)=1.E-5, CON(7)= .40
CON(9)=1., CON(10)=1.5, CON(11)=1.6, CON(12)=33.66, CON(13)=.9,
CON(14)=1.7, CON(15)=74.00, CON(16)=13, CON(17)=0., CON(18)= .1,
CON(19)= 10.
IOPT(8) = 0
PRINT(1)=300.,PRINT(2)=3600.,PRINT(3)=172800.
IOPT(2)=1, IOPT(3)=0,IOPT(4)=1
IOPT(2)=0,
IOPT(13)=1
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Sample SCRAM Input/Output Listing - Continued

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          &END
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 RAINFALL HISTORY

 YEAR MONTH  DAY  HOUR  MINUTE SECOND RAIN(CM/SEC)

 1973.    6.   28.    3.   35.     0.  0.1366667E-02  0.1366667E-02  0.1366667E-02  0.1366667E-02  0.1366667E-02  0.1366667E-02
                                       0.1366667E-02  0.1366667E-02  0.1366667E-02  0.1366667E-02
 1973.    6.   28.    3.   40.     0.  0.0            0.0            0.0            0.0            0.0            0.0
                                       0.0            0.0            0.0            0.0
 1973.    6.   28.   16.   30.     0.  0.8333332E-03  0.8333332E-03  0.8333332E-03  0.8333332E-03  0.8333332E-03  0.8333332E-03
                                       0.8333332E-03  0.8333332E-03  0.8333332E-03  0.8333332E-03
 1973.    6.   28.   16.   35.     0.  0.1666665E-03  0.1666665E-03  0.1666665E-03  0.1666665E-03  0.1666665E-03  0.1666665E-03
                                       0.1666665E-03  0.1666665E-03  0.1666665E-03  0.1666665E-03
 1973.    6.   28.   16.   40.     0.  0.1333334E-03  0.1333334E-03  0.1333334E-03  0.1333334E-03  0.1333334E-03  0.1333334E-03
                                       0.1333334E-03  0.1333334E-03  0.1333334E-03  0.1333334E-03
 1973.    6.   28.   16.   50.     0.  0.0            0.0            0.0            0.0            0.0            0.0
                                       0.0            0.0            0.0            0.0
 1973.    7.    8.   16.   52.     0.  0.8888885E-03  0.8888885E-03  0.8888885E-03  0.8888885E-03  0.8888885E-03  0.8888885E-03
                                       0.8888885E-03  0.8888885E-03  0.8888885E-03  0.8888885E-03
 1973.    7.    8.   16.   55.     0.  0.5999999E-03  0.5999999E-03  0.5999999E-03  0.5999999E-03  0.5999999E-03  0.5999999E-03
                                       0.5999999E-03  0.5999999E-03  0.5999999E-03  0.5999999E-03
 1973.    7.    8.   17.    0.     0.  0.5833332E-03  0.5833332E-03  0.5833332E-03  0.5833332E-03  0.5833332E-03  0.5833332E-03
                                       0.5833332E-03  0.5833332E-03  0.5833332E-03  0.5833332E-03
 1973.    7.    8.   17.    2.     0.  0.6111111E-03  0.6111111E-03  0.6111111E-03  0.6111111E-03  0.6111111E-03  0.6111111E-03
                                       0.6111111E-03  0.6111111E-03  0.6111111E-03  0.6111111E-03
 1973.    7.    8.   17.    5.     0.  0.5333330E-03  0.5333330E-03  0.5333330E-03  0.5333330E-03  0.5333330E-03  0.5333330E-03
                                       0.5333330E-03  0.5333330E-03  0.5333330E-03  0.5333330E-03
 1973.    7.    8.   17.   10.     0.  0.3999998E-03  0.3999998E-03  0.3999998E-03  0.3999998E-03  0.3999998E-03  0.3999998E-03
                                       0.3999998E-03  0.3999998E-03  0.3999998E-03  0.3999998E-03
 1973.    7.    8.   17.   15.     0.  0.3666666E-03  0.3666666E-03  0.3666666E-03  0.3666666E-03  0.3666666E-03  0.3666666E-03
                                       0.3666666E-03  0.3666666E-03  0.3666666E-03  0.3666666E-03
 1973.    7.    8.   17.   20.     0.  0.3999991E-03  0.3999991E-03  0.3999991E-03  0.3999991E-03  0.3999991E-03  0.3999991E-03
                                       0.3999991E-03  0.3999991E-03  0.3999991E-03  0.3999991E-03
 1973.    7.    8.   17.   25.     0.  0.3666654E-03  0.3666654E-03  0.3666654E-03  0.3666654E-03  0.3666654E-03  0.3666654E-03
                                       0.3666654E-03  0.3666654E-03  0.3666654E-03  0.3666654E-03
 1973.    7.    8.   17.   30.     0.  0.3999996E-03  0.3999996E-03  0.3999996E-03  0.3999996E-03  0.3999996E-03  0.3999996E-03
                                       0.3999996E-03  0.3999996E-03  0.3999996E-03  0.3999996E-03
 1973.    7.    8.   17.   35.     0.  0.3666687E-03  0.3666687E-03  0.3666687E-03  0.3666687E-03  0.3666687E-03  0.3666687E-03
                                       0.3666687E-03  0.3666687E-03  0.3666687E-03  0.3666687E-03
 1973.    7.    8.   17.   40.     0.  0.1666641E-03  0.1666641E-03  0.1666641E-03  0.1666641E-03  0.1666641E-03  0.1666641E-03
                                       0.1666641E-03  0.1666641E-03  0.1666641E-03  0.1666641E-03
 1973.    7.    8.   17.   45.     0.  0.1166677E-03  0.1166677E-03  0.1166677E-03  0.1166677E-03  0.1166677E-03  0.1166677E-03
                                       0.1166677E-03  0.1166677E-03  0.1166677E-03  0.1166677E-03
 1973.    7.    8.   17.   55.     0.  0.1222218E-03  0.1222218E-03  0.1222218E-03  0.1222218E-03  0.1222218E-03  0.1222218E-03
                                       0.1222218E-03  0.1222218E-03  0.1222218E-03  0.1222218E-03
 1973.    7.    8.   18.   10.     0.  0.1333332E-03  0.1333332E-03  0.1333332E-03  0.1333332E-03  0.1333332E-03  0.1333332E-03
                                       0.1333332E-03  0.1333332E-03  0.1333332E-03  0.1333332E-03
 1973.    7.    8.   18.   20.     0.  0.1111137E-03  0.1111137E-03  0.1111137E-03  0.1111137E-03  0.1111137E-03  0.1111137E-03
                                       0.1111137E-03  0.1111137E-03  0.1111137E-03  0.1111137E-03
 1973.    7.    8.   18.   23.     0.  0.0            0.0            0.0            0.0            0.0            0.0
                                       0.0            0.0            0.0            0.0
 1973.    7.   16.   20.   35.     0.  0.2999997E-03  0.2999997E-03  0.2999997E-03  0.2999997E-03  0.2999997E-03  0.2999997E-03
                                       0.2999997E-03  0.2999997E-03  0.2999997E-03  0.2999997E-03
 1973.    7.   16.   20.   40.     0.  0.4666664E-03  0.4666664E-03  0.4666664E-03  0.4666664E-03  0.4666664E-03  0.4666664E-03
                                       0.4666664E-03  0.4666664E-03  0.4666664E-03  0.4666664E-03
 1973.    7.   16.   20.   45.     0.  0.5555556E-03  0.5555556E-03  0.5555556E-03  0.5555556E-03  0.5555556E-03  0.5555556E-03
                                       0.5555556E-03  0.5555556E-03  0.5555556E-03  0.5555556E-03
 1973.    7.   16.   20.   48.     0.  0.4999998E-03  0.4999998E-03  0.4999998E-03  0.4999998E-03  0.4999998E-03  0.4999998E-03
                                       0.4999998E-03  0.4999998E-03  0.4999998E-03  0.4999998E-03
 1973.    7.   16.   20.   50.     0.  0.5555553E-03  0.5555553E-03  0.5555553E-03  0.5555553E-03  0.5555553E-03  0.5555553E-03
                                       0.5555553E-03  0.5555553E-03  0.5555553E-03  0.5555553E-03
 1973.    7.   16.   20.   53.     0.  0.5833332E-03  0.5833332E-03  0.5833332E-03  0.5833332E-03  0.5833332E-03  0.5833332E-03
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Sample SCRAM Input/Output Listing - Continued

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EPA ENVIRONMENTAL DATA

YEAR MONTH  DAY  HOUR  MINUTE SECOND  WIND V          TEMPERATURE     SOLAR RADIATION  ATMOS PRES     RELATIVE HUMIDITY

1973.   1.    1.    0.    0.    0.  0.1034024E 03  0.2852777E 02  0.5000000E 01  0.1013300E 04  0.6000000E 00
1973.   1.    1.    0.    0.    0.  0.1034024E 03  0.2852777E 02  0.5000000E 01  0.1013300E 04  0.6000000E 00
1973.   1.    1.    0.    0.    0.  0.1034024E 03  0.2852777E 02  0.5000000E 01  0.1013300E 04  0.6000000E 00
1973.   1.    1.    0.    0.    0.  0.1034024E 03  0.2852777E 02  0.5000000E 01  0.1013300E 04  0.6000000E 00
1973.   1.    1.    0.    0.    0.  0.1034024E 03  0.2852777E 02  0.5000000E 01  0.1013300E 04  0.6000000E 00
1973.   1.    1.    0.    0.    0.  0.1034024E 03  0.2852777E 02  0.5000000E 01  0.1013300E 04  0.6000000E 00
1973.   1.    1.    0.    0.    0.  0.1034024E 03  0.2852777E 02  0.5000000E 01  0.1013300E 04  0.6000000E 00
1973.   1.    1.    0.    0.    0.  0.1034024E 03  0.2852777E 02  0.5000000E 01  0.1013300E 04  0.6000000E 00
1973.   1.    1.    0.    0.    0.  0.1034024E 03  0.2852777E 02  0.5000000E 01  0.1013300E 04  0.6000000E 00
1973.   1.    1.    0.    0.    0.  0.1034024E 03  0.2852777E 02  0.5000000E 01  0.1013300E 04  0.6000000E 00
1973.   7.    1.    0.    0.    0.  0.9980130E 02  0.2666666E 02  0.5000000E 01  0.1013300E 04  0.6500000E 00
1973.   7.    1.    0.    0.    0.  0.9980130E 02  0.2666666E 02  0.5000000E 01  0.1013300E 04  0.6500000E 00
1973.   7.    1.    0.    0.    0.  0.9980130E 02  0.2666666E 02  0.5000000E 01  0.1013300E 04  0.6500000E 00
1973.   7.    1.    0.    0.    0.  0.9980130E 02  0.2666666E 02  0.5000000E 01  0.1013300E 04  0.6500000E 00
1973.   7.    1.    0.    0.    0.  0.9980130E 02  0.2666666E 02  0.5000000E 01  0.1013300E 04  0.6500000E 00
1973.   7.    1.    0.    0.    0.  0.9980130E 02  0.2666666E 02  0.5000000E 01  0.1013300E 04  0.6500000E 00
1973.   7.    1.    0.    0.    0.  0.9980130E 02  0.2666666E 02  0.5000000E 01  0.1013300E 04  0.6500000E 00
1973.   7.    1.    0.    0.    0.  0.9980130E 02  0.2666666E 02  0.5000000E 01  0.1013300E 04  0.6500000E 00
1973.   7.    1.    0.    0.    0.  0.9980130E 02  0.2666666E 02  0.5000000E 01  0.1013300E 04  0.6500000E 00
1973.   7.    1.    0.    0.    0.  0.9980130E 02  0.2666666E 02  0.5000000E 01  0.1013300E 04  0.6500000E 00
1973.   7.    8.    0.    0.    0.  0.1008302E 03  0.2514444E 02  0.5000000E 01  0.1013300E 04  0.8200000E 00
1973.   7.    8.    0.    0.    0.  0.1008302E 03  0.2514444E 02  0.5000000E 01  0.1013300E 04  0.8200000E 00
1973.   7.    8.    0.    0.    0.  0.1008302E 03  0.2514444E 02  0.5000000E 01  0.1013300E 04  0.8200000E 00
1973.   7.    8.    0.    0.    0.  0.1008302E 03  0.2514444E 02  0.5000000E 01  0.1013300E 04  0.8200000E 00
1973.   7.    8.    0.    0.    0.  0.1008302E 03  0.2514444E 02  0.5000000E 01  0.1013300E 04  0.8200000E 00
1973.   7.    8.    0.    0.    0.  0.1008302E 03  0.2514444E 02  0.5000000E 01  0.1013300E 04  0.8200000E 00
1973.   7.    8.    0.    0.    0.  0.1008302E 03  0.2514444E 02  0.5000000E 01  0.1013300E 04  0.8200000E 00
1973.   7.    8.    0.    0.    0.  0.1008302E 03  0.2514444E 02  0.5000000E 01  0.1013300E 04  0.8200000E 00
1973.   7.    8.    0.    0.    0.  0.1008302E 03  0.2514444E 02  0.5000000E 01  0.1013300E 04  0.8200000E 00
1973.   7.    8.    0.    0.    0.  0.1008302E 03  0.2514444E 02  0.5000000E 01  0.1013300E 04  0.8200000E 00
1973.   7.   17.    0.    0.    0.  0.8848361E 02  0.2645555E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   17.    0.    0.    0.  0.8848361E 02  0.2645555E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   17.    0.    0.    0.  0.8848361E 02  0.2645555E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   17.    0.    0.    0.  0.8848361E 02  0.2645555E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   17.    0.    0.    0.  0.8848361E 02  0.2645555E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   17.    0.    0.    0.  0.8848361E 02  0.2645555E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   17.    0.    0.    0.  0.8848361E 02  0.2645555E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   17.    0.    0.    0.  0.8848361E 02  0.2645555E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   17.    0.    0.    0.  0.8848361E 02  0.2645555E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   17.    0.    0.    0.  0.8848361E 02  0.2645555E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   30.    0.    0.    0.  0.8076703E 02  0.2747777E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   30.    0.    0.    0.  0.8076703E 02  0.2747777E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   30.    0.    0.    0.  0.8076703E 02  0.2747777E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   30.    0.    0.    0.  0.8076703E 02  0.2747777E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   30.    0.    0.    0.  0.8076703E 02  0.2747777E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   30.    0.    0.    0.  0.8076703E 02  0.2747777E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   30.    0.    0.    0.  0.8076703E 02  0.2747777E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   30.    0.    0.    0.  0.8076703E 02  0.2747777E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   30.    0.    0.    0.  0.8076703E 02  0.2747777E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   7.   30.    0.    0.    0.  0.8076703E 02  0.2747777E 02  0.5000000E 01  0.1013300E 04  0.8000000E 00
1973.   9.    1.    0.    0.    0.  0.2932305E 03  0.2411110E 02  0.5500000E 01  0.1013300E 04  0.7500000E 00
1973.   9.    1.    0.    0.    0.  0.2932305E 03  0.2411110E 02  0.5500000E 01  0.1013300E 04  0.7500000E 00
1973.   9.    1.    0.    0.    0.  0.2932305E 03  0.2411110E 02  0.5500000E 01  0.1013300E 04  0.7500000E 00
1973.   9.    1.    0.    0.    0.  0.2932305E 03  0.2411110E 02  0.5500000E 01  0.1013300E 04  0.7500000E 00
1973.   9.    1.    0.    0.    0.  0.2932305E 03  0.2411110E 02  0.5500000E 01  0.1013300E 04  0.7500000E 00
1973.   9.    1.    0.    0.    0.  0.2932305E 03  0.2411110E 02  0.5500000E 01  0.1013300E 04  0.7500000E 00
1973.   9.    1.    0.    0.    0.  0.2932305E 03  0.2411110E 02  0.5500000E 01  0.1013300E 04  0.7500000E 00
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Sample SCRAM Input/Output Listing - Continued

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                                              DHTAB ARRAY, SOIL TYPE  1

                  THETA             D(THETA) DIFFUSIVITY   H(THETA) PRESSURE HEAD       SIGMA D DELTA THETA

       1      0.600000E-01               0.100000E-06            -0.600000E 06             0.200000E-08
       2      0.800000E-01               0.999999E-06            -0.900000E 05             0.220000E-07
       3      0.100000E 00               0.600000E-05            -0.400000E 05             0.142000E-06
       4      0.120000E 00               0.100000E-04            -0.100000E 05             0.342000E-06
       5      0.140000E 00               0.300000E-04            -0.700000E 04             0.942001E-06
       6      0.160000E 00               0.530000E-04            -0.470000E 04             0.200200E-05
       7      0.180000E 00               0.730000E-04            -0.200000E 04             0.346200E-05
       8      0.200000E 00               0.900000E-04            -0.100000E 04             0.526200E-05
       9      0.220000E 00               0.150000E-03            -0.800000E 03             0.826200E-05
      10      0.240000E 00               0.300000E-03            -0.680000E 03             0.142620E-04
      11      0.260000E 00               0.430000E-03            -0.570000E 03             0.228620E-04
      12      0.280000E 00               0.600000E-03            -0.450000E 03             0.348620E-04
      13      0.300000E 00               0.700000E-03            -0.330000E 03             0.488619E-04
      14      0.320000E 00               0.800000E-03            -0.220000E 03             0.648620E-04
      15      0.340000E 00               0.900000E-03            -0.100000E 03             0.828619E-04
      16      0.360000E 00               0.950000E-03            -0.900000E 02             0.101862E-03
      17      0.380000E 00               0.100000E-02            -0.770000E 02             0.121862E-03
      18      0.400000E 00               0.130000E-02            -0.600000E 02             0.147862E-03
      19      0.420000E 00               0.160000E-02            -0.500000E 02             0.179862E-03
      20      0.440000E 00               0.180000E-02            -0.400000E 02             0.215862E-03
      21      0.460000E 00               0.200000E-02            -0.200000E 02             0.255862E-03
      22      0.480000E 00               0.700000E-02            -0.100000E 02             0.395861E-03
      23      0.500000E 00               0.100000E-01             0.0                      0.595862E-03


                                              DHTAB ARRAY, SOIL TYPE  2

                  THETA             D(THETA) DIFFUSIVITY   H(THETA) PRESSURE HEAD       SIGMA D DELTA THETA

       1      0.500000E-01               0.680000E-05            -0.600000E 06             0.136000E-06
       2      0.700000E-01               0.860000E-05            -0.900000E 05             0.308000E-06
       3      0.900000E-01               0.133000E-04            -0.400000E 05             0.568000E-06
       4      0.110000E 00               0.230000E-04            -0.100000E 05             0.102800E-05
       5      0.130000E 00               0.400000E-04            -0.700000E 04             0.182800E-05
       6      0.150000E 00               0.683000E-04            -0.470000E 04             0.318800E-05
       7      0.170000E 00               0.120000E-03            -0.200000E 04             0.558800E-05
       8      0.190000E 00               0.180000E-03            -0.100000E 04             0.918800E-05
       9      0.210000E 00               0.280000E-03            -0.800000E 03             0.147880E-04
      10      0.230000E 00               0.400000E-03            -0.680000E 03             0.227880E-04
      11      0.250000E 00               0.560000E-03            -0.570000E 03             0.339880E-04
      12      0.270000E 00               0.800000E-03            -0.450000E 03             0.499880E-04
      13      0.290000E 00               0.120000E-02            -0.330000E 03             0.739879E-04
      14      0.310000E 00               0.170000E-02            -0.220000E 03             0.107988E-03
      15      0.330000E 00               0.240000E-02            -0.100000E 03             0.155988E-03
      16      0.350000E 00               0.320000E-02            -0.900000E 02             0.219988E-03
      17      0.370000E 00               0.440000E-02            -0.770000E 02             0.307988E-03
      18      0.390000E 00               0.600000E-02            -0.600000E 02             0.427988E-03
      19      0.410000E 00               0.800000E-02            -0.500000E 02             0.587987E-03
      20      0.430000E 00               0.110000E-01            -0.400000E 02             0.807987E-03
      21      0.450000E 00               0.150000E-01            -0.200000E 02             0.110799E-02
      22      0.470000E 00               0.190000E-01            -0.100000E 02             0.148799E-02
      23      0.490000E 00               0.260000E-01             0.0                      0.200799E-02
```

Sample SCRAM Input/Output Listing - Continued

```
                                          BEGIN PESTICIDE SIMULATION

WATERSHED NAME: P-01

PESTICIDE NAME: DIPHENAMID

START DATE:
JUL  8, 1973, 16 HRS, 52 MIN,  0.0     SEC                                        JULIAN DATE  2441873.20277778D 00

END DATE:
JUL 16, 1973, 21 HRS, 30 MIN,  0.0     SEC                                        JULIAN DATE  2441881.39583333D 00

PLANT DATE:
JUN 13, 1973,  0 HRS,  0 MIN,  0.0     SEC                                        JULIAN DATE  2441847.50000000D 00

MATURITY DATE:
SEP 12, 1973,  0 HRS,  0 MIN,  0.0     SEC                                        JULIAN DATE  2441938.50000000D 00

HARVEST DATE:
NOV  1, 1973,  0 HRS,  0 MIN,  0.0     SEC                                        JULIAN DATE  2441988.50000000D 00
                                          WATERSHED ZONE DEFINITION

ZONE #  SOIL TYPE         AREA        SLOPE      LENGTH       WIDTH      DENSITY    SEDIMENT       NO.        LAYER
                                                                                    INCREMENTS    LAYERS    THICKNESS
                          CM**2      PERCENT       CM           CM       GM/CM**2                              CM


  1     SERL LM         1699679.      4.000     2667.000    2286.000       1.600       3.000       15.000      1.000
  2     SERL LM        38080912.      3.000    26098.496    3347.085       1.600       3.000       15.000      1.000
  3     LT CLAY        59488752.      4.000    12953.996    5714.996       1.600       3.000       15.000      1.000
  4     LT CLAY        26668768.      3.000     8762.996    4762.496       1.600       3.000       15.000      1.000
  5     LT CLAY        20072400.      3.000     9143.996    3238.500       1.600       3.000       15.000      1.000
  6     LT CLAY        42856160.      2.000    11048.996    5333.996       1.600       3.000       15.000      1.000
  7     LT CLAY        22055360.      4.000     9905.996    5714.996       1.600       3.000       15.000      1.000
  8     LT CLAY        16996784.      4.000     6857.996    3809.999       1.600       3.000       15.000      1.000
  9     LT CLAY        24685808.      2.000     3429.000    6476.996       1.600       3.000       15.000      1.000
 10     LT CLAY        17320528.      4.000     6857.996    3619.499       1.600       3.000       15.000      1.000
                                            RUNOFF DESCRIPTION

ZONE #         TO          %          TO          %          TO          %          TO          %


  1            21      100.000        0          0.0         0          0.0         0          0.0
  2             1      100.000        0          0.0         0          0.0         0          0.0
  3            10       33.333       10         66.667       0          0.0         0          0.0
  4             3       12.500       10         87.500       0          0.0         0          0.0
  5             6       66.667       10         33.333       0          0.0         0          0.0
  6             7       66.667       10         33.333       0          0.0         0          0.0
  7             1      100.000        0          0.0         0          0.0         0          0.0
  8             1       75.000       10         25.000       0          0.0         0          0.0
  9             5       20.000       10         80.000       0          0.0         0          0.0
 10             8       50.000       10         50.000       0          0.0         0          0.0
```

Sample SCRAM Input/Output Listing - Continued

```
   INITIAL CONDITION OUTPUT
JUL  8, 1973, 16 HRS, 52 MIN,  0.0     SEC                                                    JULIAN DATE  2441873.202777787 00

   RAINFALL RATE =CM/SEC
  0.8889E-03  0.8889E-03  0.8889E-03  0.8889E-03  0.8889E-03  0.8889E-03  0.8889E-03  0.8889E-03  0.8889E-03  0.8889E 03

                                                  ZONE DEPTH PROFILE

                                                        ZONE #
PROFILE            1         2         3         4         5         6         7         8         9        10
THETA
   1             0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
   2             0.500     0.500     0.500     0.500     0.500     0.500     0.500     0.500     0.500     0.500
   3             0.061     0.061     0.061     0.061     0.061     0.061     0.061     0.061     0.061     0.061
   4             0.062     0.062     0.062     0.062     0.062     0.062     0.062     0.062     0.062     0.062
   5             0.063     0.063     0.063     0.063     0.063     0.063     0.063     0.063     0.063     0.063
   6             0.064     0.064     0.064     0.064     0.064     0.064     0.064     0.064     0.064     0.064
   7             0.065     0.065     0.065     0.065     0.065     0.065     0.065     0.065     0.065     0.065
   8             0.066     0.066     0.066     0.066     0.066     0.066     0.066     0.066     0.066     0.066
   9             0.067     0.067     0.067     0.067     0.067     0.067     0.067     0.067     0.067     0.067
  10             0.068     0.068     0.068     0.068     0.068     0.068     0.068     0.068     0.068     0.068
  11             0.069     0.069     0.069     0.069     0.069     0.069     0.069     0.069     0.069     0.069
  12             0.070     0.070     0.070     0.070     0.070     0.070     0.070     0.070     0.070     0.070
  13             0.070     0.070     0.070     0.070     0.070     0.070     0.070     0.070     0.070     0.070
  14             0.070     0.070     0.070     0.070     0.070     0.070     0.070     0.070     0.070     0.070
  15             0.070     0.070     0.070     0.070     0.070     0.070     0.070     0.070     0.070     0.070
  CIT            0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
```

Sample SCRAM Input/Output Listing - Continued

```
   NORMAL CONDITION OUTPUT
JUL  8, 1973, 17 HRS,  0 MIN,  0.0     SEC                                                   JULIAN DATE  2441873.208333333 00

   RAINFALL RATE =CM/SEC
  0.5832E-03  0.5833E-03  0.5833E-03  0.5833E-03  0.5833E-03  0.5833E-03  0.5833E-03  0.5833E-03  0.5833E-03  0.5833E 02

                                                  ZONE DEPTH PROFILE

                                                        ZONE #
PROFILE         1           2           3           4           5           6           7           8           9          10
THETA
    1         0.744       0.0         0.0         0.0         0.0         0.025       0.018       0.141       0.0         0.268
    2         0.489       0.421       0.488       0.484       0.490       0.495       0.495       0.495       0.476       0.495
    3         0.440       0.394       0.328       0.328       0.328       0.329       0.329       0.329       0.327       0.329
    4         0.269       0.144       0.068       0.068       0.068       0.068       0.068       0.068       0.068       0.068
    5         0.065       0.063       0.063       0.063       0.063       0.063       0.063       0.063       0.063       0.063
    6         0.064       0.064       0.064       0.064       0.064       0.064       0.064       0.064       0.064       0.064
    7         0.065       0.065       0.065       0.065       0.065       0.065       0.065       0.065       0.065       0.065
    8         0.066       0.066       0.066       0.066       0.066       0.066       0.066       0.066       0.066       0.066
    9         0.067       0.067       0.067       0.067       0.067       0.067       0.067       0.067       0.067       0.067
   10         0.068       0.068       0.068       0.068       0.068       0.068       0.068       0.068       0.068       0.068
   11         0.069       0.069       0.069       0.069       0.069       0.069       0.069       0.069       0.069       0.069
   12         0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
   13         0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
   14         0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
   15         0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
  CIT         0.568       0.337       0.262       0.257       0.264       0.269       0.269       0.269       0.248       0.269
DISSOLVED PESTICIDE
    1       0.377E 02   0.373E 02   0.364E 02   0.366E 02   0.363E 02   0.361E 02   0.361E 02   0.361E 02   0.371E 02   0.361E 02
    2       0.284E 00   0.277E 00   0.298E 00   0.298E 00   0.298E 00   0.298E 00   0.298E 00   0.298E 00   0.298E 00   0.298E 00
    3       0.363E-03   0.322E-03   0.378E-03   0.378E-03   0.378E-03   0.378E-03   0.378E-03   0.378E-03   0.378E-03   0.378E-03
    4       0.234E-06   0.219E-06   0.242E-06   0.242E-06   0.242E-06   0.242E-06   0.242E-06   0.242E-06   0.242E-06   0.242E-06
    5       0.216E-09   0.216E-09   0.230E-09   0.230E-09   0.230E-09   0.230E-09   0.230E-09   0.230E-09   0.230E-09   0.230E-09
    6       0.226E-12   0.226E-12   0.236E-12   0.236E-12   0.236E-12   0.236E-12   0.236E-12   0.236E-12   0.236E-12   0.236E-12
    7       0.239E-15   0.239E-15   0.247E-15   0.247E-15   0.247E-15   0.247E-15   0.247E-15   0.247E-15   0.247E-15   0.247E-15
    8       0.253E-18   0.253E-18   0.262E-18   0.262E-18   0.262E-18   0.262E-18   0.262E-18   0.262E-18   0.262E-18   0.262E-18
    9       0.270E-21   0.270E-21   0.278E-21   0.278E-21   0.278E-21   0.278E-21   0.278E-21   0.278E-21   0.278E-21   0.278E-21
   10       0.288E-24   0.288E-24   0.296E-24   0.296E-24   0.296E-24   0.296E-24   0.296E-24   0.296E-24   0.296E-24   0.296E-24
   11       0.309E-27   0.309E-27   0.318E-27   0.318E-27   0.318E-27   0.318E-27   0.318E-27   0.318E-27   0.318E-27   0.318E-27
   12       0.339E-30   0.339E-30   0.344E-30   0.344E-30   0.344E-30   0.344E-30   0.344E-30   0.344E-30   0.344E-30   0.344E-30
   13       0.362E-33   0.362E-33   0.372E-33   0.372E-33   0.372E-33   0.372E-33   0.372E-33   0.372E-33   0.372E-33   0.372E-33
ADSORBED PESTICIDE
    1       0.989E 01   0.987E 01   0.960E 01   0.963E 01   0.958E 01   0.955E 01   0.955E 01   0.955E 01   0.970E 01   0.955E 01
    2       0.450E 00   0.441E 00   0.298E 00   0.298E 00   0.298E 00   0.298E 00   0.298E 00   0.298E 00   0.298E 00   0.298E 00
    3       0.118E-02   0.101E-02   0.713E-03   0.713E-03   0.713E-03   0.713E-03   0.713E-03   0.713E-03   0.713E-03   0.713E-03
    4       0.150E-05   0.142E-05   0.111E-05   0.111E-05   0.111E-05   0.111E-05   0.111E-05   0.111E-05   0.111E-05   0.111E-05
    5       0.280E-08   0.280E-08   0.219E-08   0.219E-08   0.219E-08   0.219E-08   0.219E-08   0.219E-08   0.219E-08   0.219E-08
    6       0.592E-11   0.582E-11   0.452E-11   0.452E-11   0.452E-11   0.452E-11   0.452E-11   0.452E-11   0.452E-11   0.452E-11
    7       0.122E-13   0.122E-13   0.944E-14   0.944E-14   0.944E-14   0.944E-14   0.944E-14   0.944E-14   0.944E-14   0.944E-14
    8       0.257E-16   0.257E-16   0.199E-16   0.199E-16   0.199E-16   0.199E-16   0.199E-16   0.199E-16   0.199E-16   0.199E-16
    9       0.542E-19   0.542E-19   0.419E-19   0.419E-19   0.419E-19   0.419E-19   0.419E-19   0.419E-19   0.419E-19   0.419E-19
   10       0.115E-21   0.115E-21   0.885E-22   0.885E-22   0.885E-22   0.885E-22   0.885E-22   0.885E-22   0.885E-22   0.885E-22
   11       0.244E-24   0.244E-24   0.188E-24   0.188E-24   0.188E-24   0.188E-24   0.188E-24   0.188E-24   0.188E-24   0.188E-24
   12       0.523E-27   0.523E-27   0.404E-27   0.404E-27   0.404E-27   0.404E-27   0.404E-27   0.404E-27   0.404E-27   0.404E-27
   13       0.112E-29   0.112E-29   0.863E-30   0.863E-30   0.863E-30   0.863E-30   0.863E-30   0.863E-30   0.863E-30   0.863E-30
```

Sample SCRAM Input/Output Listing - Continued

```
ZONE #  SEDIMENT                RUNOFF    TOTAL
         LOAD                   RATE      PESTICIDE
        GM/CM/SEC               CM/S      MICROGRAMS


   1  0.4691E-01  0.1849E-01  0.3450E 02
   2  0.0         0.0         0.3232E 02
   3  0.0         0.0         0.3372E 02
   4  0.0         0.0         0.3372E 02
   5  0.0         0.0         0.3372E 02
   6  0.6593E-02  0.6980E-04  0.3372E 02
   7  0.6314E-02  0.1134E-03  0.3372E 02
   8  0.1414E-01  0.1236E-02  0.3372E 02
   9  0.0         0.0         0.3372E 02
  10  0.3071E-01  0.2424E-02  0.3372E 02

         AVERAGE     AVERAGE        TOTAL
PROFILE  PESTICIDE   PESTICIDE    PESTICIDE
 DEPTH   DISSOLVED   ADSORBED
         MICROGRAMS  MICROGRAMS   MICROGRAMS
   1  0.1760E 02  0.1544E 02  0.3304E 02
   2  0.1020E 00  0.5250E 00  0.6270E 00
   3  0.3559E-04  0.1263E-02  0.1298E-02
   4  0.1507E-07  0.1885E-05  0.1900E-05
   5  0.1455E-10  0.3696E-08  0.3710E-08
   6  0.1522E-13  0.7641E-11  0.7657E-11
   7  0.1671E-16  0.1599E-13  0.1600E-13
   8  0.1742E-19  0.3364E-16  0.3366E-16
   9  0.1879E-22  0.7098E-19  0.7100E-19
  10  0.2031E-25  0.1500E-21  0.1500E-21
  11  0.2214E-28  0.3194E-24  0.3194E-24
  12  0.2397E-31  0.6846E-27  0.6846E-27
  13  0.2593E-34  0.1463E-29  0.1463E-29

ACCUMULATED RUNOFF:                                ACCUMULATED PESTICIDE LOSS:               INSTANTANEOUS PESTICIDE LOSS
    WATER =          7655.LITERS                        IN WATER =        2.30GRAMS/HECTARE        826.63MICROGRAMS/LITER
 SEDIMENT =           100.KILOGRAMS                  ON SEDIMENT =        0.01GRAMS/HECTARE          0.27MICROGRAMS/GRAM


TOTAL WATER LOSS                                   % OF PESTICIDE APPLIED                     RATE OF PESTICIDE LOSS
   FROM EVAPOTRANSPIRATION                             IN WATER = 0.0682                       297588.38MICROGRAMS/LITER/HR
   =            0. LITERS                           ON SEDIMENT = 0.0003                            97.56MICROGRAMS/GRAM/HR

ACCUMULATED INFILTRATION
WATER LOSS =            0. LITERS

WATER BALANCE:
WATER IN =  0.4602187E 06 LITERS
WATER OUT = 0.4602207E 06 LITERS
 ZONE  1       INFILTRATION RATE=  0.4532E-02  CM/SEC
 ZONE  2       INFILTRATION RATE=  0.6000E-03  CM/SEC
 ZONE  3       INFILTRATION RATE=  0.2287E-02  CM/SEC
 ZONE  4       INFILTRATION RATE=  0.1847E-02  CM/SEC
 ZONE  5       INFILTRATION RATE=  0.2542E-02  CM/SEC
 ZONE  6       INFILTRATION RATE=  0.3019E-02  CM/SEC
 ZONE  7       INFILTRATION RATE=  0.3019E-02  CM/SEC
 ZONE  8       INFILTRATION RATE=  0.3019E-02  CM/SEC
 ZONE  9       INFILTRATION RATE=  0.9215E-03  CM/SEC
 ZONE 10       INFILTRATION RATE=  0.3019E-02  CM/SEC
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Sample SCRAM Input/Output Listing - Continued

```
   NORMAL CONDITION OUTPUT
JUL  8, 1973, 17 HRS, 10 MIN,  0.0     SEC  .                                                    JULIAN DATE  2441873.215277780 00

  RAINFALL RATE =CM/SEC
 0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03

                                                         ZONE DEPTH PROFILE

                                                              ZONE #
PROFILE        1           2           3           4           5           6           7           8           9           10
THETA
   1         1.234       0.0         0.033       0.027       0.038       0.077       0.068       0.218       0.011       0.431
   2         0.457       0.436       0.482       0.482       0.482       0.482       0.482       0.482       0.482       0.482
   3         0.452       0.427       0.455       0.455       0.455       0.455       0.455       0.455       0.455       0.455
   4         0.412       0.376       0.166       0.165       0.166       0.166       0.166       0.166       0.165       0.166
   5'        0.291       0.123       0.063       0.063       0.063       0.063       0.063       0.063       0.063       0.063
   6         0.069       0.064       0.064       0.064       0.064       0.064       0.064       0.064       0.064       0.064
   7         0.065       0.065       0.065       0.065       0.065       0.065       0.065       0.065       0.065       0.065
   8         0.066       0.066       0.066       0.066       0.066       0.066       0.066       0.066       0.066       0.066
   9         0.067       0.067       0.067       0.067       0.067       0.067       0.067       0.067       0.067       0.067
  10         0.068       0.068       0.068       0.068       0.068       0.068       0.068       0.068       0.068       0.068
  11         0.069       0.069       0.069       0.069       0.069       0.069       0.069       0.069       0.069       0.069
  12         0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
  13         0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
  14         0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
  15         0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
 CIT         0.931       0.677       0.480       0.479       0.480       0.480       0.480       0.480       0.479       0.480
DISSOLVED PESTICIDE
   1      0.365E 02   0.378E 02   0.361E 02   0.361E 02   0.361E 02   0.361E 02   0.361E 02   0.361E 02   0.361E 02   0.361E 02
   2      0.491E 00   0.532E 00   0.588E 00   0.588E 00   0.588E 00   0.587E 00   0.587E 00   0.587E 00   0.588E 00   0.587E 00
   3      0.219E-02   0.128E-02   0.208E-02   0.208E-02   0.208E-02   0.208E-02   0.208E-02   0.208E-02   0.207E-02   0.208E-02
   4      0.295E-05   0.575E-06   0.730E-06   0.729E-06   0.730E-06   0.731E-06   0.731E-06   0.731E-06   0.727E-06   0.731E-06
   5      0.541E-09   0.243E-09   0.280E-09   0.280E-09   0.280E-09   0.280E-09   0.280E-09   0.280E-09   0.280E-09   0.280E-09
   6      0.243E-12   0.233E-12   0.251E-12   0.251E-12   0.251E-12   0.251E-12   0.251E-12   0.251E-12   0.251E-12   0.251E-12
   7      0.245E-15   0.242E-15   0.255E-15   0.255E-15   0.255E-15   0.255E-15   0.255E-15   0.255E-15   0.255E-15   0.255E-15
   8      0.257E-18   0.255E-18   0.266E-18   0.266E-18   0.266E-18   0.266E-18   0.266E-18   0.266E-18   0.266E-18   0.266E-18
   9      0.272E-21   0.271E-21   0.280E-21   0.280E-21   0.280E-21   0.280E-21   0.280E-21   0.280E-21   0.290E-21   0.280E-21
  10      0.289E-24   0.288E-24   0.297E-24   0.297E-24   0.297E-24   0.297E-24   0.297E-24   0.297E-24   0.297E-24   0.297E-24
  11      0.310E-27   0.309E-27   0.319E-27   0.319E-27   0.319E-27   0.319E-27   0.319E-27   0.319E-27   0.319E-27   0.319E-27
  12      0.335E-30   0.335E-30   0.345E-30   0.345E-30   0.345E-30   0.345E-30   0.345E-30   0.345E-30   0.345E-30   0.345E-30
  13      0.362E-33   0.362E-33   0.373E-33   0.373E-33   0.373E-33   0.373E-33   0.373E-33   0.373E-33   0.373E-33   0.373E-33
ADSORBED PESTICIDE
   1      0.980E 01   0.102E 02   0.955E 01   0.955E 01   0.955E 01   0.955E 01   0.955E 01   0.955E 01   0.956E 01   0.955E 01
   2      0.485E 00   0.593E 00   0.444E 00   0.444E 00   0.444E 00   0.444E 00   0.444E 00   0.444E 00   0.444E 00   0.444E 00
   3      0.260E-02   0.248E-02   0.194E-02   0.194E-02   0.194E-02   0.194E-02   0.194E-02   0.194E-02   0.194E-02   0.194E-02
   4      0.513E-05   0.234E-05   0.212E-05   0.212E-05   0.212E-05   0.212E-05   0.212E-05   0.212E-05   0.212E-05   0.212E-05
   5      0.363E-08   0.231E-08   0.245E-08   0.245E-08   0.245E-08   0.245E-08   0.245E-08   0.245E-08   0.245E-08   0.245E-08
   6      0.458E-11   0.450E-11   0.468E-11   0.468E-11   0.468E-11   0.468E-11   0.468E-11   0.468E-11   0.468E-11   0.468E-11
   7      0.934E-14   0.930E-14   0.961E-14   0.961E-14   0.961E-14   0.961E-14   0.961E-14   0.961E-14   0.961E-14   0.961E-14
   8      0.195E-16   0.195E-16   0.200E-16   0.200E-16   0.200E-16   0.200E-16   0.200E-16   0.200E-16   0.200E-16   0.200E-16
   9      0.410E-19   0.410E-19   0.421E-19   0.421E-19   0.421E-19   0.421E-19   0.421E-19   0.421E-19   0.421E-19   0.421E-19
  10      0.865E-22   0.865E-22   0.887E-22   0.887E-22   0.887E-22   0.887E-22   0.887E-22   0.887E-22   0.887E-22   0.887E-22
  11      0.184E-24   0.184E-24   0.189E-24   0.189E-24   0.189E-24   0.189E-24   0.189E-24   0.189E-24   0.189E-24   0.189E-24
  12      0.394E-27   0.394E-27   0.404E-27   0.404E-27   0.404E-27   0.404E-27   0.404E-27   0.404E-27   0.404E-27   0.404E-27
  13      0.842E-30   0.842E-30   0.863E-30   0.863E-30   0.863E-30   0.863E-30   0.863E-30   0.863E-30   0.863E-30   0.863E-30
```

Sample SCRAM Input/Output Listing - Continued

```
ZONE #  SEDIMENT          RUNOFF   TOTAL
          LOAD             RATE    PESTICIDE
        GM/CM/SEC          CM/S    MICROGRAMS


    1   0.1782E 00  0.1951E-01   0.3334E 02
    2   0.0         0.0          0.3405E 02
    3   0.6441E-02  0.2049E-03   0.3368E 02
    4   0.4663E-02  0.1981E-03   0.3368E 02
    5   0.5332E-02  0.2422E-03   0.3368E 02
    6   0.6346E-02  0.2345E-03   0.3368E 02
    7   0.8226E-02  0.4696E-03   0.3368E 02
    8   0.2620E-01  0.1930E-02   0.3368E 02
    9   0.2133E-02  0.2072E-03   0.3368E 02
   10   0.6644E-01  0.3712E-02   0.3368E 02

         AVERAGE     AVERAGE        TOTAL
PROFILE  PESTICIDE   PESTICIDE    PESTICIDE
  DEPTH  DISSOLVED    ADSORBED
         MICROGRAMS  MICROGRAMS   MICROGRAMS
      1  0.1724E 02  0.1544E 02   0.3268E 02
      2  0.2590E 00  0.7407E 00   0.9997E 00
      3  0.4134E-03  0.3298E-02   0.3711E-02
      4  0.1297E-06  0.3910E-05   0.4040E-05
      5  0.1961E-10  0.4089E-08   0.4108E-08
      6  0.1616E-13  0.7445E-11   0.7461E-11
      7  0.1667E-16  0.1528E-13   0.1529E-13
      8  0.1766E-19  0.3187E-16   0.3189E-16
      9  0.1892E-22  0.6697E-19   0.6699E-19
     10  0.2038E-25  0.1412E-21   0.1413E-21
     11  0.2218E-28  0.3004E-24   0.3004E-24
     12  0.2399E-31  0.6435E-27   0.6435E-27
     13  0.2594E-34  0.1374E-29   0.1374E-29

ACCUMULATED RUNOFF:                                 ACCUMULATED PESTICIDE LOSS:              INSTANTANEOUS PESTICIDE LOSS
    WATER =       24046.LITERS                           IN WATER =      7.25GRAMS/HECTARE            816.85MICROGRAMS/LITER
 SEDIMENT =         279.KILOGRAMS                    ON SEDIMENT =       0.03GRAMS/HECTARE              0.27MICROGRAMS/GRAM


TOTAL WATER LOSS                                    % OF PESTICIDE APPLIED                   RATE OF PESTICIDE LOSS
   FROM EVAPOTRANSPIRATION                              IN WATER = 0.2153                      49011.02MICROGRAMS/LITER/HR
   =           0. LITERS                             ON SEDIMENT = 0.0008                           16.48MICROGRAMS/GRAM/HR

ACCUMULATED INFILTRATION
WATER LOSS =          0. LITERS

WATER BALANCE:
WATER IN =  0.5519909E 06 LITERS
WATER OUT = 0.5519946E 06 LITERS
 ZONE  1       INFILTRATION RATE=  0.5569E-03 CM/SEC
 ZONE  2       INFILTRATION RATE=  0.5333E-03 CM/SEC
 ZONE  3       INFILTRATION RATE=  0.3165E-03 CM/SEC
 ZONE  4       INFILTRATION RATE=  0.3168E-03 CM/SEC
 ZONE  5       INFILTRATION RATE=  0.3164E-03 CM/SEC
 ZONE  6       INFILTRATION RATE=  0.3162E-03 CM/SEC
 ZONE  7       INFILTRATION RATE=  0.3162E-03 CM/SEC
 ZONE  8       INFILTRATION RATE=  0.3162E-03 CM/SEC
 ZONE  9       INFILTRATION RATE=  0.3177E-03 CM/SEC
 ZONE 10       INFILTRATION RATE=  0.3162E-03 CM/SEC
```

Sample SCRAM Input/Output Listing - Continued

```
   NORMAL CONDITION OUTPUT
JUL  8, 1973, 17 HRS, 20 MIN,  0.0     SEC                                                          JULIAN DATE  2441873.222222220 00

   RAINFALL RATE =CM/SEC
  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E 03

                                                   ZONE DEPTH PROFILE

                                                         ZONE #
PROFILE         1          2          3          4          5          6          7          8          9         10
THETA
    1         0.738      0.0        0.014      0.011      0.016      0.049      0.044      0.181      0.004      0.309
    2         0.472      0.440      0.491      0.491      0.491      0.491      0.491      0.491      0.491      0.491
    3         0.463      0.425      0.467      0.467      0.467      0.467      0.467      0.467      0.467      0.467
    4         0.436      0.392      0.307      0.307      0.307      0.308      0.308      0.308      0.307      0.308
    5         0.396      0.318      0.074      0.074      0.074      0.074      0.074      0.074      0.074      0.074
    6         0.235      0.083      0.064      0.064      0.064      0.064      0.064      0.064      0.064      0.064
    7         0.067      0.065      0.065      0.065      0.065      0.065      0.065      0.065      0.065      0.065
    8         0.066      0.066      0.066      0.066      0.066      0.066      0.066      0.066      0.066      0.066
    9         0.067      0.067      0.067      0.067      0.067      0.067      0.067      0.067      0.067      0.067
   10         0.068      0.068      0.068      0.068      0.068      0.068      0.068      0.068      0.068      0.068
   11         0.069      0.069      0.069      0.069      0.069      0.069      0.069      0.069      0.069      0.069
   12         0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070
   13         0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070
   14         0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070
   15         0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070
   CIT        1.253      0.907      0.653      0.653      0.653      0.653      0.651      0.653      0.652      0.653
 DISSOLVED PESTICIDE
    1      0.352E 02  0.371E 02  0.351E 02  0.351E 02  0.351E 02  0.351E 02  0.351E 02  0.351E 02  0.351E 02  0.351E 02
    2      0.763E 00  0.727E 00  0.889E 00  0.889E 00  0.888E 00  0.888E 00  0.888E 00  0.888E 00  0.889E 00  0.888E 00
    3      0.573E-02  0.411E-02  0.825E-02  0.825E-02  0.825E-02  0.825E-02  0.825E-02  0.825E-02  0.825E-02  0.825E-02
    4      0.286E-04  0.927E-05  0.999E-05  0.998E-05  0.100E-04  0.100E-04  0.100E-04  0.100E-04  0.995E-05  0.100E-04
    5      0.371E-07  0.732E-08  0.931E-09  0.930E-09  0.932E-09  0.933E-09  0.933E-09  0.933E-09  0.927E-09  0.933E-09
    6      0.274E-11  0.284E-12  0.281E-12  0.281E-12  0.281E-12  0.281E-12  0.281E-12  0.281E-12  0.281E-12  0.281E-12
    7      0.265E-15  0.250E-15  0.263E-15  0.263E-15  0.263E-15  0.263E-15  0.263E-15  0.263E-15  0.263E-15  0.263E-15
    8      0.261E-18  0.296E-18  0.270E-18  0.270E-18  0.270E-18  0.270E-18  0.270E-18  0.270E-18  0.270E-18  0.270E-18
    9      0.274E-21  0.273E-21  0.282E-21  0.282E-21  0.282E-21  0.282E-21  0.282E-21  0.282E-21  0.282E-21  0.282E-21
   10      0.290E-24  0.269E-24  0.298E-24  0.298E-24  0.298E-24  0.298E-24  0.298E-24  0.298E-24  0.298E-24  0.298E-24
   11      0.310E-27  0.310E-27  0.319E-27  0.319E-27  0.319E-27  0.319E-27  0.319E-27  0.319E-27  0.319E-27  0.319E-27
   12      0.335E-30  0.335E-30  0.345E-30  0.345E-30  0.345E-30  0.345E-30  0.345E-30  0.345E-30  0.345E-30  0.345E-30
   13      0.363E-33  0.362E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33
 ADSORBED PESTICIDE
    1      0.959E 01  0.101E 02  0.940E 01  0.940E 01  0.940E 01  0.940E 01  0.940E 01  0.940E 01  0.940E 01  0.940E 01
    2      0.599E 00  0.713E 00  0.566E 00  0.566E 00  0.566E 00  0.566E 00  0.566E 00  0.566E 00  0.566E 00  0.566E 00
    3      0.459E-02  0.494E-02  0.438E-02  0.438E-02  0.438E-02  0.438E-02  0.438E-02  0.438E-02  0.438E-02  0.438E-02
    4      0.195E-04  0.120E-04  0.988E-05  0.987E-05  0.988E-05  0.989E-05  0.989E-05  0.989E-05  0.985E-05  0.989E-05
    5      0.436E-07  0.872E-08  0.497E-08  0.497E-08  0.497E-08  0.498E-08  0.498E-08  0.498E-08  0.496E-08  0.498E-08
    6      0.173E-10  0.505E-11  0.500E-11  0.503E-11  0.500E-11  0.500E-11  0.500E-11  0.500E-11  0.500E-11  0.500E-11
    7      0.978E-14  0.967E-14  0.978E-14  0.978E-14  0.978E-14  0.978E-14  0.978E-14  0.978E-14  0.978E-14  0.978E-14
    8      0.197E-16  0.196E-16  0.202E-16  0.202E-16  0.202E-16  0.202E-16  0.202E-16  0.202E-16  0.202E-16  0.202E-16
    9      0.412E-19  0.411E-19  0.423E-19  0.423E-19  0.423E-19  0.423E-19  0.423E-19  0.423E-19  0.423E-19  0.423E-19
   10      0.867E-22  0.867E-22  0.889E-22  0.889E-22  0.889E-22  0.889E-22  0.889E-22  0.889E-22  0.889E-22  0.889E-22
   11      0.184E-24  0.184E-24  0.189E-24  0.189E-24  0.189E-24  0.189E-24  0.189E-24  0.189E-24  0.189E-24  0.189E-24
   12      0.394E-27  0.394E-27  0.404E-27  0.404E-27  0.404E-27  0.404E-27  0.404E-27  0.404E-27  0.404E-27  0.404E-27
   13      0.842E-30  0.842E-30  0.863E-30  0.863E-30  0.863E-30  0.863E-30  0.863E-30  0.863E-30  0.863E-30  0.863E-30
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Sample SCRAM Input/Output Listing - Continued

```
ZONE #  SEDIMENT            RUNOFF   TOTAL
          LOAD               RATE    PESTICIDE
        GM/CM/SEC            CM/S    MICROGRAMS


     1  0.7509E-01  0.1851E-01  0.3327E 02
     2  0.0         0.0         0.3398E 02
     3  0.2846E-02  0.7809E-04  0.3361E 02
     4  0.2111E-02  0.6761E-04  0.3361E 02
     5  0.2392E-02  0.9371E-04  0.3361E 02
     6  0.2932E-02  0.1429E-03  0.3361E 02
     7  0.3482E-02  0.2870E-03  0.3361E 02
     8  0.1478E-01  0.1638E-02  0.3361E 02
     9  0.9819E-03  0.4623E-04  0.3361E 02
    10  0.2829E-01  0.2839E-02  0.3361E 02

          AVEPAGE     AVERAGE       TOTAL
PROFILE  PESTICIDE   PESTICIDE    PESTICIDE
  DEPTH  DISSOLVED    ADSORBED
         MICROGRAMS  MICROGRAMS  MICROGRAMS
     1  0.1709E 02  0.1519E 02  0.3228E 02
     2  0.3955E 00  0.9345E 00  0.1330E 01
     3  0.2440E-02  0.7124E-02  0.9564E-02
     4  0.2011E-05  0.1770E-04  0.1971E-04
     5  0.9401E-09  0.1474E-07  0.1568E-07
     6  0.3218E-13  0.9980E-11  0.1001E-10
     7  0.1728E-16  0.1560E-13  0.1562E-13
     8  0.1793E-19  0.3215E-16  0.3217E-16
     9  0.1906E-22  0.6727E-19  0.6729E-19
    10  0.2046E-25  0.1416E-21  0.1416E-21
    11  0.2222E-28  0.3007E-24  0.3008E-24
    12  0.2401E-31  0.6439E-27  0.6439E-27
    13  0.2595E-34  0.1375E-29  0.1375E-29

ACCUMULATED RUNOFF:                          ACCUMULATED PESTICIDE LOSS:                   INSTANTANEOUS PESTICIDE LOSS
    WATEP =        44430.LITEPS                   IN WATER =       13.40GRAMS/HECTARE           815.93MICROGRAMS/LITER
 SEDIMENT =          492.KILOGRAMS              ON SEDIMENT =       0.05GRAMS/HECTARE             0.27MICROGRAMS/GRAM


TOTAL WATER LOSS                             % OF PESTICIDE APPLIED                        RATE OF PESTICIDE LOSS
   FROM EVAPOTRANSPIRATION                       IN WATER = 0.3982                            86227.00MICROGRAMS/LITER/HR
   =              0. LITERS                   ON SEDIMENT = 0.0015                              28.91MICROGRAMS/GRAM/HR

ACCUMULATED INFILTRATION
WATEP LOSS =            0. LITEPS

WATER BALANCE:
WATER IN =  0.6140761E 06 LITEPS
WATER OUT = 0.6140770E 06 LITEPS
 ZONE  1       INFILTRATION RATE=  0.6849E-03 CM/SEC
 ZONE  2       INFILTPATION RATE=  0.3667E-03 CM/SEC
 ZONE  3       INFILTPATION RATE=  0.3760E-03 CM/SEC
 ZONE  4       INFILTRATION RATE=  0.3762E-03 CM/SEC
 ZONE  5       INFILTRATION RATE=  0.3760E-03 CM/SEC
 ZONE  6       INFILTPATION RATE=  0.3760E-03 CM/SEC
 ZONE  7       INFILTRATION RATE=  0.3760E-03 CM/SEC
 ZONF  8       INFILTRATION RATE=  0.3760E-03 CM/SEC
 ZONE  9       INFILTPATION RATE=  0.3763E-03 CM/SEC
 ZONE 10       INFILTRATION RATE=  0.3760E-03 CM/SEC
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Sample SCRAM Input/Output Listing - Continued

```
  NORMAL CONDITION OUTPUT
JUL  8, 1973, 17 HRS, 30 MIN,  0.0     SEC                                                      JULIAN DATE  2441873.22916667D 00

  RAINFALL RATE =CM/SEC
 0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03  0.4000E-03

                                                     ZONE DEPTH PROFILE

                                                            ZONE #
PROFILE          1          2          3          4          5          6          7          8          9         10
THETA
   1         0.803      0.0        0.024      0.019      0.027      0.061      0.054      0.191      0.009      0.353
   2         0.471      0.447      0.490      0.490      0.490      0.490      0.490      0.490      0.490      0.490
   3         0.467      0.439      0.473      0.473      0.473      0.473      0.473      0.473      0.473      0.473
   4         0.446      0.414      0.389      0.389      0.389      0.389      0.389      0.389      0.388      0.389
   5         0.417      0.371      0.130      0.130      0.130      0.130      0.130      0.130      0.129      0.130
   6         0.371      0.214      0.064      0.064      0.064      0.064      0.064      0.064      0.064      0.064
   7         0.160      0.067      0.065      0.065      0.065      0.065      0.065      0.065      0.065      0.065
   8         0.066      0.066      0.066      0.066      0.066      0.066      0.066      0.066      0.066      0.066
   9         0.067      0.067      0.067      0.067      0.067      0.067      0.067      0.067      0.067      0.067
  10         0.068      0.068      0.068      0.068      0.068      0.068      0.068      0.068      0.068      0.068
  11         0.069      0.069      0.069      0.069      0.069      0.069      0.069      0.070      0.070      0.070
  12         0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070
  13         0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070
  14         0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070
  15         0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070
 CIT         1.516      1.137      0.795      0.795      0.795      0.795      0.795      0.795      0.794      0.795
DISSOLVED PESTICIDE
   1     0.348E 02  0.362E 02  0.347E 02  0.347E 02  0.347E 02  0.347E 02  0.347E 02  0.347E 02  0.347E 02  0.347E 02
   2     0.924E 00  0.931E 00  0.118E 01  0.118E 01  0.118E 01  0.118E 01  0.118E 01  0.118E 01  0.118E 01  0.118E 01
   3     0.116E-01  0.861E-02  0.202E-01  0.202E-01  0.202E-01  0.202E-01  0.202E-01  0.202E-01  0.202E-01  0.202E-01
   4     0.103E-03  0.531E-04  0.106E-03  0.106E-03  0.106E-03  0.106E-03  0.106E-03  0.106E-03  0.106E-03  0.106E-03
   5     0.629E-06  0.113E-06  0.375E-07  0.374E-07  0.375E-07  0.376E-07  0.376E-07  0.376E-07  0.372E-07  0.376E-07
   6     0.100E-08  0.123E-10  0.121E-11  0.121E-11  0.121E-11  0.122E-11  0.122E-11  0.122E-11  0.120E-11  0.122E-11
   7     0.527E-13  0.337E-15  0.279E-15  0.279E-15  0.279E-15  0.279E-15  0.279E-15  0.279E-15  0.279E-15  0.279E-15
   8     0.396E-18  0.263E-18  0.274E-18  0.274E-18  0.274E-18  0.274E-18  0.274E-18  0.274E-18  0.274E-18  0.276E-18
   9     0.276E-21  0.275E-21  0.284E-21  0.284E-21  0.284E-21  0.284E-21  0.284E-21  0.284E-21  0.284E-21  0.284E-21
  10     0.291E-24  0.290E-24  0.299E-24  0.299E-24  0.299E-24  0.299E-24  0.299E-24  0.299E-24  0.299E-24  0.299E-24
  11     0.311E-27  0.311E-27  0.320E-27  0.320E-27  0.320E-27  0.320E-27  0.320E-27  0.320E-27  0.320E-27  0.320E-27
  12     0.336E-30  0.336E-30  0.345E-30  0.345E-30  0.345E-30  0.345E-30  0.345E-30  0.345E-30  0.349E-30  0.345E-30
  13     0.363E-33  0.363E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33
ADSORBED PESTICIDE
   1     0.953E 01  0.100E 02  0.933E 01  0.933E 01  0.933E 01  0.933E 01  0.933E 01  0.933E 01  0.933E 01  0.933E 01
   2     0.703E 00  0.825E 00  0.667E 00  0.667E 00  0.667E 00  0.667E 00  0.667E 00  0.667E 00  0.668E 00  0.667E 00
   3     0.692E-02  0.763E-02  0.742E-02  0.742E-02  0.742E-02  0.742E-02  0.742E-02  0.742E-02  0.742E-02  0.742E-02
   4     0.416E-04  0.336E-04  0.397E-04  0.397E-04  0.397E-04  0.397E-04  0.397E-04  0.397E-04  0.397E-04  0.397E-04
   5     0.231E-06  0.856E-07  0.437E-07  0.436E-07  0.437E-07  0.437E-07  0.437E-07  0.437E-07  0.434E-07  0.437E-07
   6     0.612E-09  0.463E-10  0.118E-10  0.118E-10  0.118E-10  0.118E-10  0.118E-10  0.118E-10  0.118E-10  0.118E-10
   7     0.220E-12  0.113E-13  0.101E-13  0.101E-13  0.101E-13  0.101E-13  0.101E-13  0.101E-13  0.101E-13  0.101E-13
   8     0.251E-16  0.198E-16  0.204E-16  0.204E-16  0.204E-16  0.204E-16  0.204E-16  0.204E-16  0.204E-16  0.204E-16
   9     0.414E-19  0.413E-19  0.425E-19  0.425E-19  0.425E-19  0.425E-19  0.425E-19  0.425E-19  0.429E-19  0.429E-19
  10     0.869E-22  0.868E-22  0.891E-22  0.891E-22  0.891E-22  0.891E-22  0.891E-22  0.891E-22  0.891E-22  0.891E-22
  11     0.184E-24  0.184E-24  0.189E-24  0.189E-24  0.189E-24  0.189E-24  0.189E-24  0.189E-24  0.189E-24  0.189E-24
  12     0.395E-27  0.395E-27  0.405E-27  0.405E-27  0.409E-27  0.409E-27  0.405E-27  0.409E-27  0.409E-27  0.405E-27
  13     0.842E-30  0.842E-30  0.864E-30  0.864E-30  0.864E-30  0.864E-30  0.864E-30  0.864E-30  0.864E-30  0.864E-30
```

Sample SCRAM Input/Output Listing - Continued

```
ZONE #  SEDIMENT            RUNOFF    TOTAL
          LOAD               RATE     PESTICIDE
        GM/CM/SEC            CM/S     MICROGRAMS


   1  0.1062E 00   0.1993E-01   0.3322E 02
   2  0.0          0.0          0.3393E 02
   3  0.2985E-02   0.1360E-03   0.3396E 02
   4  0.2173E-02   0.1287E-03   0.3396E 02
   5  0.2482E-02   0.1622E-03   0.3396E 02
   6  0.2593E-02   0.1812E-03   0.3396E 02
   7  0.3860E-02   0.3635E-03   0.3396E 02
   8  0.1793E-01   0.1718E-02   0.3396E 02
   9  0.9980E-03   0.1240E-03   0.3396E 02
  10  0.3424E-01   0.3146E-02   0.3396E 02

         AVERAGE      AVERAGE        TOTAL
PROFILE  PESTICIDE    PESTICIDE     PESTICIDE
  DEPTH  DISSOLVED    ADSORBED
         MICROGRAMS   MICROGRAMS   MICROGRAMS
   1  0.1685E 02   0.1507E 02   0.3192E 02
   2  0.5297E 00   0.1099E 01   0.1628E 01
   3  0.7164E-02   0.1183E-01   0.1899E-01
   4  0.1731E-04   0.6288E-04   0.8019E-04
   5  0.2767E-07   0.1065E-06   0.1342E-06
   6  0.1612E-10   0.1234E-09   0.1395E-09
   7  0.3667E-15   0.4990E-13   0.5026E-13
   8  0.1909E-19   0.3330E-16   0.3331E-16
   9  0.1921E-22   0.6757E-19   0.6759E-19
  10  0.2054E-25   0.1419E-21   0.1419E-21
  11  0.2226E-28   0.3011E-24   0.3011E-24
  12  0.2404E-31   0.6443E-27   0.6443E-27
  13  0.2997E-34   0.1375E-29   0.1375E-29

 ACCUMULATED RUNOFF:                               ACCUMULATED PESTICIDE LOSS:                      INSTANTANEOUS PESTICIDE LOSS
    WATER =       61704.LITERS                         IN WATER =        18.60GRAMS/HECTARE                818.91MICROGRAMS/LITER
  SEDIMENT =         636.KILOGRAMS                 ON SEDIMENT =         0.06GRAMS/HECTARE                   9.27MICROGRAMS/GRAM


 TOTAL WATER LOSS                                  % OF PESTICIDE APPLIED                           RATE OF PESTICIDE LOSS
    FROM EVAPOTRANSPIRATION                            IN WATER = 0.5526                              64021.34MICROGRAMS/LITER/HR
    =            0. LITERS                         ON SEDIMENT = 0.0019                                  21.65MICROGRAMS/GRAM/HR

 ACCUMULATED INFILTRATION
 WATER LOSS =            0. LITERS

 WATER BALANCE:
 WATER IN =  0.6761488E 06 LITERS
 WATER OUT = 0.6761594E 06 LITERS
  ZONE  1        INFILTRATION RATE=  0.4563E-03 CM/SEC
  ZONE  2        INFILTRATION RATE=  0.3667E-03 CM/SEC
  ZONE  3        INFILTRATION RATE=  0.2443E-03 CM/SEC
  ZONE  4        INFILTRATION RATE=  0.2444E-03 CM/SEC
  ZONE  5        INFILTRATION RATE=  0.2443E-03 CM/SEC
  ZONE  6        INFILTRATION RATE=  0.2442E-03 CM/SEC
  ZONE  7        INFILTRATION RATE=  0.2442E-03 CM/SEC
  ZONE  8        INFILTRATION RATE=  0.2442E-03 CM/SEC
  ZONE  9        INFILTRATION RATE=  0.2444E-03 CM/SEC
  ZONE 10        INFILTRATION RATE=  0.2442E-03 CM/SEC
```

Sample SCRAM Input/Output Listing - Continued

```
   NORMAL CONDITION OUTPUT
 JUL  9, 1973, 17 HRS, 40 MIN,  0.0    SEC                                              JULIAN DATE  2441873.236111110 00

   RAINFALL RATE =CM/SEC
  0.1667E-03  0.1667E-03  0.1667E-03  0.1667E-03  0.1667E-03  0.1667E-03  0.1667E-03  0.1667E-03  0.1667E-03  0.1667E-03

                                                        ZONE DEPTH PROFILE

                                                              ZONE #
 PROFILE         1           2           3           4           5           6           7           8           9          10
 THETA
    1          0.482       0.0         0.023       0.017       0.027       0.066       0.058       0.217       0.086       0.409
    2          0.488       0.457       0.499       0.499       0.499       0.499       0.499       0.499       0.499       0.499
    3          0.471       0.449       0.477       0.477       0.477       0.477       0.477       0.477       0.477       0.477
    4          0.452       0.426       0.420       0.420       0.420       0.420       0.420       0.420       0.420       0.420
    5          0.429       0.395       0.220       0.220       0.220       0.220       0.220       0.220       0.219       0.220
    6          0.396       0.340       0.066       0.066       0.066       0.066       0.066       0.066       0.066       0.066
    7          0.320       0.115       0.065       0.065       0.065       0.065       0.065       0.065       0.065       0.065
    8          0.094       0.066       0.066       0.066       0.066       0.066       0.066       0.066       0.066       0.066
    9          0.067       0.067       0.067       0.067       0.067       0.067       0.067       0.067       0.067       0.067
   10          0.068       0.068       0.068       0.068       0.068       0.068       0.068       0.068       0.068       0.068
   11          0.069       0.069       0.069       0.069       0.069       0.069       0.069       0.069       0.069       0.069
   12          0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
   13          0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
   14          0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
   15          0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
  CIT          1.774       1.367       0.932       0.932       0.932       0.932       0.932       0.932       0.931       0.932
 DISSOLVED PESTICIDE
    1       0.336E 02  0.352E 02  0.338E 02  0.338E 02  0.338E 02  0.338E 02  0.338E 02  0.338E 02  0.338E 02  0.338E 02
    2       0.115E 01  0.114E 01  0.146E 01  0.146E 01  0.146E 01  0.146E 01  0.146E 01  0.146E 01  0.146E 01  0.146E 01
    3       0.201E-01  0.153E-01  0.370E-01  0.370E-01  0.370E-01  0.370E-01  0.370E-01  0.370E-01  0.370E-01  0.370E-01
    4       0.267E-03  0.157E-03  0.495E-03  0.495E-03  0.495E-03  0.495E-03  0.495E-03  0.495E-03  0.495E-03  0.495E-03
    5       0.284E-05  0.121E-05  0.127E-05  0.127E-05  0.127E-05  0.127E-05  0.127E-05  0.127E-05  0.126E-05  0.127E-05
    6       0.229E-07  0.252E-08  0.242E-09  0.241E-09  0.242E-09  0.243E-09  0.243E-09  0.243E-09  0.239E-09  0.243E-09
    7       0.614E-10  0.205E-12  0.327E-14  0.326E-14  0.328E-14  0.329E-14  0.329E-14  0.329E-14  0.323E-14  0.329E-14
    8       0.838E-14  0.893E-18  0.287E-18  0.286E-18  0.287E-18  0.287E-18  0.287E-18  0.287E-18  0.286E-18  0.287E-18
    9       0.323E-19  0.278E-21  0.286E-21  0.286E-21  0.286E-21  0.286E-21  0.286E-21  0.286E-21  0.286E-21  0.286E-21
   10       0.309E-24  0.291E-24  0.301E-24  0.301E-24  0.301E-24  0.301E-24  0.301E-24  0.301E-24  0.301E-24  0.301E-24
   11       0.311E-27  0.311E-27  0.320E-27  0.320E-27  0.320E-27  0.320E-27  0.320E-27  0.320E-27  0.320E-27  0.320E-27
   12       0.336E-30  0.336E-30  0.346E-30  0.346E-30  0.346E-30  0.346E-30  0.346E-30  0.346E-30  0.346E-30  0.346E-30
   13       0.363E-33  0.363E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33
 ADSORBED PESTICIDE
    1       0.933E 01  0.983E 01  0.918E 01  0.918E 01  0.918E 01  0.918E 01  0.918E 01  0.918E 01  0.918E 01  0.918E 01
    2       0.800E 00  0.929E 00  0.756E 00  0.757E 00  0.756E 00  0.756E 00  0.756E 00  0.756E 00  0.757E 00  0.756E 00
    3       0.955E-02  0.107E-01  0.106E-01  0.106E-01  0.106E-01  0.106E-01  0.106E-01  0.106E-01  0.106E-01  0.106E-01
    4       0.727E-04  0.636E-04  0.983E-04  0.983E-04  0.983E-04  0.983E-04  0.983E-04  0.983E-04  0.983E-04  0.983E-04
    5       0.560E-06  0.346E-06  0.347E-06  0.347E-06  0.347E-06  0.347E-06  0.347E-06  0.347E-06  0.346E-06  0.347E-06
    6       0.386E-08  0.106E-08  0.266E-09  0.265E-09  0.266E-09  0.266E-09  0.266E-09  0.266E-09  0.264E-09  0.266E-09
    7       0.140E-10  0.490E-12  0.430E-13  0.430E-13  0.431E-13  0.432E-13  0.432E-13  0.432E-13  0.427E-13  0.432E-13
    8       0.880E-14  0.404E-16  0.209E-16  0.209E-16  0.209E-16  0.209E-16  0.209E-16  0.209E-16  0.209E-16  0.209E-16
    9       0.681E-18  0.416E-19  0.426E-19  0.426E-19  0.426E-19  0.426E-19  0.426E-19  0.426E-19  0.426E-19  0.426E-19
   10       0.894E-22  0.870E-22  0.893E-22  0.893E-22  0.893E-22  0.893E-22  0.893E-22  0.893E-22  0.893E-22  0.893E-22
   11       0.185E-24  0.185E-24  0.189E-24  0.189E-24  0.189E-24  0.189E-24  0.189E-24  0.189E-24  0.189E-24  0.189E-24
   12       0.395E-27  0.395E-27  0.405E-27  0.405E-27  0.405E-27  0.405E-27  0.405E-27  0.405E-27  0.405E-27  0.405E-27
   13       0.843E-30  0.842E-30  0.864E-30  0.864E-30  0.864E-30  0.864E-30  0.864E-30  0.864E-30  0.864E-30  0.864E-30
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Sample SCRAM Input/Output Listing - Continued

```
ZONE #   SEDIMENT          RUNOFF   TOTAL
           LOAD             RATE    PESTICIDE
         GM/CM/SEC          GM/S    MICROGRAMS

    1  0.2791E-01  0.2044E-01  0.3316E 02
    2  0.0         0.0         0.3387E 02
    3  0.2746E-02  0.1062E-03  0.3350E 02
    4  0.2091E-02  0.9036E-04  0.3350E 02
    5  0.2201E-02  0.1331E-03  0.3350E 02
    6  0.2485E-02  0.1811E-03  0.3350E 02
    7  0.2580E-02  0.3554E-03  0.3350E 02
    8  0.6339E-02  0.1934E-02  0.3350E 02
    9  0.9791E-03  0.4001E-04  0.3350E 02
   10  0.1369E-01  0.3600E-02  0.3350E 02

           AVERAGE      AVERAGE        TOTAL
PROFILE   PESTICIDE    PESTICIDE     PESTICIDE
  DEPTH   DISSOLVED    ADSORBED
         MICROGRAMS   MICROGRAMS    MICROGRAMS
    1  0.1674E 02  0.1482E 02  0.3156E 02
    2  0.6638E 00  0.1245E 01  0.1909E 01
    3  0.1399E-01  0.1678E-01  0.3077E-01
    4  0.1047E-03  0.1476E-03  0.2523E-03
    5  0.2202E-06  0.5893E-06  0.8094E-06
    6  0.7923E-09  0.1128E-08  0.1921E-08
    7  0.5773E-12  0.2370E-11  0.2948E-11
    8  0.5617E-16  0.1441E-14  0.1497E-14
    9  0.2374E-21  0.1703E-18  0.1705E-18
   10  0.2071E-25  0.1426E-21  0.1426E-21
   11  0.2230E-28  0.3014E-24  0.3014E-24
   12  0.2406E-31  0.6446E-27  0.6446E-27
   13  0.2598E-34  0.1375E-29  0.1375E-29

ACCUMULATED RUNOFF:                                   ACCUMULATED PESTICIDE LOSS:                         INSTANTANEOUS PESTICIDE LOSS
   WATER =        91385.LITERS                           IN WATER =        24.50GRAMS/HECTARE                   811.72MICROGRAMS/LITER
 SEDIMENT =          774.KILOGRAMS                     ON SEDIMENT =        0.08GRAMS/HECTARE                      0.27MICROGRAMS/GRAM

TOTAL WATER LOSS                                      % OF PESTICIDE APPLIED                              RATE OF PESTICIDE LOSS
   FROM EVAPOTRANSPIRATION                               IN WATER = 0.7279                                 728951.75MICROGRAMS/LITER/HR
   =          0. LITERS                                ON SEDIMENT = 0.0023                                    244.74MICROGRAMS/GRAM/HR

ACCUMULATED INFILTRATION
WATER LOSS =          0. LITERS

WATER BALANCE:
WATER IN =  0.7382271E 06 LITERS
WATER OUT = 0.7382417E 06 LITERS
 ZONE  1      INFILTRATION RATE=  0.4044E-02 CM/SEC
 ZONE  2      INFILTRATION RATE=  0.3667E-03 CM/SEC
 ZONE  3      INFILTRATION RATE=  0.2134E-02 CM/SEC
 ZONE  4      INFILTRATION RATE=  0.2135E-02 CM/SEC
 ZONE  5      INFILTRATION RATE=  0.2134E-02 CM/SEC
 ZONE  6      INFILTRATION RATE=  0.2134E-02 CM/SEC
 ZONE  7      INFILTRATION RATE=  0.2134E-02 CM/SEC
 ZONE  8      INFILTRATION RATE=  0.2134E-02 CM/SEC
 ZONE  9      INFILTRATION RATE=  0.2135E-02 CM/SEC
 ZONE 10      INFILTRATION RATE=  0.2134E-02 CM/SEC
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Sample SCRAM Input/Output Listing - Continued

```
   NORMAL CONDITION OUTPUT
JUL  8, 1973, 17 HRS, 50 MIN. 30.56577 SEC                                                        JULIAN DATE  2441873.243409330 03

   RAINFALL RATE =CM/SEC
  0.1167E-03  0.1167E-03  0.1167E-03  0.1167E-03  0.1167E-03  0.1167E-03  0.1167E-03  0.1167E-03  0.1167E-03  0.1167E-03

                                              ZONE DEPTH PROFILE

                                                    ZONE #
 PROFILE        1          2          3          4          5          6          7          8          9          10
 THETA
    1         0.166      0.0        0.0        0.0        0.0        0.0        0.0        0.051      0.0        0.070
    2         0.476      0.432      0.483      0.482      0.483      0.489      0.489      0.492      0.481      0.492
    3         0.473      0.425      0.472      0.472      0.472      0.478      0.478      0.479      0.471      0.479
    4         0.458      0.412      0.431      0.431      0.432      0.437      0.437      0.437      0.428      0.437
    5         0.438      0.392      0.306      0.306      0.306      0.307      0.307      0.307      0.305      0.307
    6         0.413      0.356      0.083      0.083      0.083      0.083      0.083      0.083      0.083      0.083
    7         0.372      0.247      0.065      0.065      0.065      0.065      0.065      0.065      0.065      0.065
    8         0.238      0.072      0.066      0.066      0.066      0.066      0.066      0.066      0.066      0.066
    9         0.071      0.067      0.067      0.067      0.067      0.067      0.067      0.067      0.067      0.067
   10         0.068      0.068      0.068      0.068      0.068      0.068      0.068      0.068      0.068      0.068
   11         0.069      0.069      0.069      0.069      0.069      0.069      0.069      0.069      0.069      0.069
   12         0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070
   13         0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070
   14         0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070
   15         0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070      0.070
   CIT        1.992      1.456      1.025      1.023      1.026      1.044      1.044      1.049      1.018      1.049
 DISSOLVED PESTICIDE
    1      0.337E 02  0.361E 02  0.341E 02  0.341E 02  0.341E 02  0.338E 02  0.338E 02  0.336E 02  0.342E 02  0.336E 02
    2      0.140E 01  0.136E 01  0.176E 01  0.176E 01  0.176E 01  0.176E 01  0.176E 01  0.176E 01  0.176E 01  0.176E 01
    3      0.321E-01  0.246E-01  0.585E-01  0.585E-01  0.585E-01  0.585E-01  0.585E-01  0.585E-01  0.585E-01  0.585E-01
    4      0.583E-03  0.369E-03  0.137E-02  0.137E-02  0.137E-02  0.137E-02  0.137E-02  0.137E-02  0.137E-02  0.137E-02
    5      0.870E-05  0.490E-05  0.147E-04  0.146E-04  0.147E-04  0.147E-04  0.147E-04  0.147E-04  0.146E-04  0.147E-04
    6      0.121E-06  0.473E-07  0.241E-07  0.241E-07  0.242E-07  0.242E-07  0.242E-07  0.242E-07  0.240E-07  0.242E-07
    7      0.142E-08  0.141E-09  0.745E-11  0.743E-11  0.747E-11  0.749E-11  0.749E-11  0.749E-11  0.736E-11  0.749E-11
    8      0.745E-11  0.333E-13  0.149E-15  0.148E-15  0.149E-15  0.150E-15  0.150E-15  0.150E-15  0.146E-15  0.150E-15
    9      0.661E-14  0.370E-18  0.455E-21  0.454E-21  0.455E-21  0.456E-21  0.456E-21  0.456E-21  0.451E-21  0.456E-21
   10      0.909E-18  0.465E-24  0.302E-24  0.302E-24  0.302E-24  0.302E-24  0.302E-24  0.302E-24  0.302E-24  0.302E-24
   11      0.406E-23  0.312E-27  0.321E-27  0.321E-27  0.321E-27  0.321E-27  0.321E-27  0.321E-27  0.321E-27  0.321E-27
   12      0.726E-30  0.336E-30  0.346E-30  0.346E-30  0.346E-30  0.346E-30  0.346E-30  0.346E-30  0.346E-30  0.346E-30
   13      0.363E-33  0.363E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33  0.373E-33
 ADSORBED PESTICIDE
    1      0.935E 01  0.997E 01  0.923E 01  0.924E 01  0.923E 01  0.918E 01  0.919E 01  0.916E 01  0.924E 01  0.916E 01
    2      0.894E 00  0.103E 01  0.841E 00  0.841E 00  0.841E 00  0.841E 00  0.841E 00  0.841E 00  0.842E 00  0.841E 00
    3      0.126E-01  0.141E-01  0.138E-01  0.138E-01  0.138E-01  0.138E-01  0.138E-01  0.138E-01  0.138E-01  0.138E-01
    4      0.115E-03  0.104E-03  0.179E-03  0.179E-03  0.179E-03  0.179E-03  0.179E-03  0.179E-03  0.179E-03  0.179E-03
    5      0.108E-05  0.788E-06  0.146E-05  0.146E-05  0.146E-05  0.147E-05  0.147E-05  0.147E-05  0.146E-05  0.147E-05
    6      0.103E-07  0.596E-08  0.399E-08  0.399E-08  0.399E-08  0.400E-08  0.400E-08  0.400E-08  0.397E-08  0.400E-08
    7      0.888E-10  0.228E-10  0.406E-11  0.406E-11  0.407E-11  0.408E-11  0.408E-11  0.408E-11  0.404E-11  0.408E-11
    8      0.478E-12  0.198E-13  0.828E-15  0.826E-15  0.830E-15  0.833E-15  0.833E-15  0.833E-15  0.819E-15  0.833E-15
    9      0.907E-15  0.286E-17  0.559E-19  0.559E-19  0.560E-19  0.561E-19  0.561E-19  0.561E-19  0.557E-19  0.561E-19
   10      0.574E-18  0.119E-21  0.896E-22  0.896E-22  0.896E-22  0.896E-22  0.896E-22  0.896E-22  0.896E-22  0.896E-22
   11      0.488E-22  0.185E-24  0.190E-24  0.190E-24  0.190E-24  0.190E-24  0.190E-24  0.190E-24  0.190E-24  0.190E-24
   12      0.621E-27  0.395E-27  0.405E-27  0.405E-27  0.405E-27  0.405E-27  0.405E-27  0.405E-27  0.405E-27  0.405E-27
   13      0.843E-30  0.843E-30  0.864E-30  0.864E-30  0.864E-30  0.864E-30  0.864E-30  0.864E-30  0.864E-30  0.864E-30
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Sample SCRAM Input/Output Listing - Continued

```
ZONE #  SEDIMENT             RUNOFF    TOTAL
          LOAD                RATE     PESTICIDE
        GM/GM/SEC             CM/S     MICROGRAMS

     1  0.9599E-02   0.4167E-02   0.3312E 02
     2  0.0          0.0          0.3383E 02
     3  0.0          0.0          0.3345E 02
     4  0.0          0.0          0.3345E 02
     5  0.0          0.0          0.3345E 02
     6  0.0          0.0          0.3345E 02
     7  0.0          0.0          0.3345E 02
     8  0.1365E-02   0.4925E-03   0.3345E 02
     9  0.0          0.0          0.3345E 02
    10  0.3040E-02   0.6922E-03   0.3345E 02

          AVERAGE      AVERAGE         TOTAL
PROFILE  PESTICIDE    PESTICIDE      PESTICIDE
 DEPTH   DISSOLVED     ADSORBED
        MICROGRAMS   MICROGRAMS     MICROGRAMS
     1  0.1626E 02   0.1487E 02   0.3113E 02
     2  0.7926E 00   0.1385E 01   0.2178E 01
     3  0.2279E-01   0.2196E-01   0.4475E-01
     4  0.3747E-03   0.2637E-03   0.6385E-03
     5  0.1509E-05   0.2174E-05   0.3682E-05
     6  0.6920E-08   0.7739E-08   0.1463E-07
     7  0.3527E-10   0.2307E-10   0.5831E-10
     8  0.5306E-13   0.8078E-13   0.1338E-12
     9  0.4497E-16   0.1456E-15   0.1905E-15
    10  0.6274E-20   0.9199E-19   0.9826E-19
    11  0.2843E-25   0.8041E-23   0.8073E-23
    12  0.2681E-31   0.6812E-27   0.6812E-27
    13  0.2599E-34   0.1376E-29   0.1376E-29

ACCUMULATED RUNOFF:                            ACCUMULATED PESTICIDE LOSS:                  INSTANTANEOUS PESTICIDE LOSS
    WATER =       94818.LITERS                     IN WATER =      28.51GRAMS/HECTARE            799.98MICROGRAMS/LITER
 SEDIMENT =         846.KILOGRAMS                ON SEDIMENT =      0.09GRAMS/HECTARE              0.28MICROGRAMS/GRAM


TOTAL WATER LOSS                               % OF PESTICIDE APPLIED                       RATE OF PESTICIDE LOSS
   FROM EVAPOTRANSPIRATION                         IN WATER = 0.8469                          69995.69MICROGRAMS/LITER/HR
   =              0. LITERS                    ON SEDIMENT = 0.0026                              24.13MICROGRAMS/GRAM/HR

ACCUMULATED INFILTRATION
WATER LOSS =              0. LITERS

WATER BALANCE:
WATER IN  =  0.7621291E 06 LITERS
WATER OUT =  0.7621471E 06 LITERS
 ZONE   1       INFILTRATION RATE=   0.3490E-03 CM/SEC
 ZONE   2       INFILTRATION RATE=   0.1167E-03 CM/SEC
 ZONE   3       INFILTRATION RATE=   0.1167E-03 CM/SEC
 ZONE   4       INFILTRATION RATE=   0.1167E-03 CM/SEC
 ZONE   5       INFILTRATION RATE=   0.1167E-03 CM/SEC
 ZONE   6       INFILTRATION RATE=   0.1167E-03 CM/SEC
 ZONE   7       INFILTRATION RATE=   0.1167E-03 CM/SEC
 ZONE   8       INFILTRATION RATE=   0.1905E-03 CM/SEC
 ZONE   9       INFILTRATION RATE=   0.1167E-03 CM/SEC
 ZONE  10       INFILTRATION RATE=   0.1905E-03 CM/SEC
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Sample SCRAM Input/Output Listing - Continued

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SPECIAL  CONDITION OUTPUT
JUL  8, 1973, 17 HRS, 59 MIN,  3.96273 SEC                                              JULIAN DATE  2441873.249351420 09

  RAINFALL RATE =CM/SEC
 0.1222E-03  0.1222E-03  0.1222E-03  0.1222E-03  0.1222E-03  0.1222E-03  0.1222E-03  0.1222E-03  0.1222E-03  0.1222E-03

                                                  ZONE DEPTH PROFILE

                                                      ZONE #
PROFILE        1           2           3           4           5           6           7           8           9           10
THETA
   1         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
   2         0.472       0.425       0.480       0.480       0.480       0.482       0.482       0.491       0.479       0.492
   3         0.469       0.416       0.469       0.469       0.469       0.472       0.472       0.480       0.468       0.481
   4         0.456       0.404       0.431       0.430       0.431       0.439       0.438       0.451       0.428       0.452
   5         0.443       0.386       0.338       0.338       0.339       0.343       0.343       0.348       0.336       0.348
   6         0.421       0.357       0.118       0.118       0.118       0.119       0.119       0.120       0.117       0.120
   7         0.390       0.305       0.065       0.065       0.065       0.065       0.065       0.065       0.065       0.065
   8         0.335       0.105       0.066       0.066       0.066       0.066       0.066       0.066       0.066       0.066
   9         0.115       0.067       0.067       0.067       0.067       0.067       0.067       0.067       0.067       0.067
  10         0.068       0.068       0.068       0.068       0.068       0.068       0.068       0.068       0.068       0.068
  11         0.069       0.069       0.069       0.069       0.069       0.069       0.069       0.069       0.069       0.069
  12         0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
  13         0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
  14         0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
  15         0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070       0.070
  CIT        2.154       1.517       1.086       1.084       1.087       1.105       1.105       1.141       1.079       1.142
DISSOLVED PESTICIDE
   1       0.336E 02   0.362E 02   0.339E 02   0.339E 02   0.339E 02   0.338E 02   0.338E 02   0.334E 02   0.339E 02   0.333E 02
   2       0.160E 01   0.155E 01   0.200E 01   0.200E 01   0.200E 01   0.200E 01   0.200E 01   0.200E 01   0.200E 01   0.200E 01
   3       0.442E-01   0.340E-01   0.786E-01   0.786E-01   0.785E-01   0.787E-01   0.787E-01   0.789E-01   0.786E-01   0.788E-01
   4       0.987E-03   0.635E-03   0.244E-02   0.244E-02   0.244E-02   0.245E-02   0.245E-02   0.245E-02   0.243E-02   0.245E-02
   5       0.182E-04   0.108E-04   0.502E-04   0.501E-04   0.502E-04   0.506E-04   0.506E-04   0.508E-04   0.500E-04   0.508E-04
   6       0.305E-06   0.170E-06   0.276E-06   0.275E-06   0.276E-06   0.279E-06   0.279E-06   0.280E-06   0.273E-06   0.280E-06
   7       0.523E-08   0.189E-08   0.527E-09   0.525E-09   0.527E-09   0.533E-09   0.533E-09   0.534E-09   0.520E-09   0.534E-09
   8       0.825E-10   0.494E-11   0.308E-12   0.306E-12   0.308E-12   0.312E-12   0.312E-12   0.312E-12   0.301E-12   0.312E-12
   9       0.422E-12   0.339E-14   0.192E-16   0.190E-16   0.193E-16   0.196E-16   0.196E-16   0.196E-16   0.186E-16   0.196E-16
  10       0.103E-14   0.292E-18   0.282E-22   0.279E-22   0.284E-22   0.291E-22   0.291E-22   0.291E-22   0.268E-22   0.291E-22
  11       0.128E-17   0.603E-24   0.327E-27   0.327E-27   0.327E-27   0.327E-27   0.327E-27   0.327E-27   0.327E-27   0.327E-27
  12       0.430E-21   0.392E-30   0.346E-30   0.346E-30   0.346E-30   0.346E-30   0.346E-30   0.346E-30   0.346E-30   0.346E-30
  13       0.925E-26   0.363E-33   0.374E-33   0.374E-33   0.374E-33   0.374E-33   0.374E-33   0.374E-33   0.374E-33   0.374E-33
ADSORBED PESTICIDE
   1       0.933E 01   0.998E 01   0.921E 01   0.921E 01   0.920E 01   0.919E 01   0.919E 01   0.912E 01   0.921E 01   0.911E 01
   2       0.967E 00   0.111E 01   0.906E 00   0.906E 00   0.906E 00   0.905E 00   0.905E 00   0.904E 00   0.906E 00   0.905E 00
   3       0.152E-01   0.170E-01   0.164E-01   0.164E-01   0.164E-01   0.164E-01   0.164E-01   0.164E-01   0.164E-01   0.164E-01
   4       0.157E-03   0.144E-03   0.250E-03   0.250E-03   0.250E-03   0.251E-03   0.251E-03   0.251E-03   0.250E-03   0.251E-03
   5       0.167E-05   0.125E-05   0.302E-05   0.302E-05   0.302E-05   0.304E-05   0.304E-05   0.304E-05   0.301E-05   0.304E-05
   6       0.177E-07   0.126E-07   0.167E-07   0.167E-07   0.168E-07   0.169E-07   0.169E-07   0.169E-07   0.166E-07   0.169E-07
   7       0.191E-09   0.105E-09   0.498E-10   0.497E-10   0.498E-10   0.501E-10   0.501E-10   0.502E-10   0.494E-10   0.502E-10
   8       0.197E-11   0.376E-12   0.738E-13   0.736E-13   0.739E-13   0.744E-13   0.744E-13   0.745E-13   0.730E-13   0.745E-13
   9       0.105E-13   0.612E-15   0.294E-16   0.292E-16   0.294E-16   0.297E-16   0.297E-16   0.298E-16   0.288E-16   0.298E-16
  10       0.359E-16   0.294E-18   0.129E-20   0.128E-20   0.129E-20   0.131E-20   0.131E-20   0.131E-20   0.125E-20   0.131E-20
  11       0.833E-19   0.158E-22   0.192E-24   0.192E-24   0.192E-24   0.192E-24   0.192E-24   0.192E-24   0.192E-24   0.192E-24
  12       0.898E-22   0.432E-27   0.405E-27   0.405E-27   0.405E-27   0.405E-27   0.405E-27   0.405E-27   0.405E-27   0.405E-27
  13       0.192E-25   0.843E-30   0.864E-30   0.864E-30   0.864E-30   0.864E-30   0.864E-30   0.864E-30   0.864E-30   0.864E-30
```

Sample SCRAM Input/Output Listing - Continued

```
ZONE #  SEDIMENT            RUNOFF  TOTAL
          LOAD               RATE   PESTICIDE
        GM/CM/SEC            CM/S   MICROGRAMS


     1  0.0          0.0            0.3311E 02
     2  0.0          0.0            0.3382E 02
     3  0.0          0.0            0.3345E 02
     4  0.0          0.0            0.3345E 02
     5  0.0          0.0            0.3345E 02
     6  0.0          0.0            0.3345E 02
     7  0.0          0.0            0.3345E 02
     8  0.0          0.0            0.3345E 02
     9  0.0          0.0            0.3345E 02
    10  0.0          0.0            0.3345E 02

     .    AVERAGE      AVERAGE       TOTAL
PROFILE  PESTICIDE    PESTICIDE    PESTICIDE
  DEPTH  DISSOLVED     ADSORBED
         MICROGRAMS   MICROGRAMS   MICROGRAMS
     1   0.1613E 02   0.1484E 02   0.3097E 02
     2   0.9120E 00   0.1509E 01   0.2421E 01
     3   0.3241E-01   0.2687E-01   0.5929E-01
     4   0.8083E-03   0.3877E-03   0.1196E-02
     5   0.7275E-05   0.4768E-05   0.1204E-04
     6   0.4002E-07   0.3136E-07   0.7138E-07
     7   0.2901E-09   0.1415E-09   0.4316E-09
     8   0.1498E-11   0.6163E-12   0.2114E-11
     9   0.4718E-14   0.2497E-14   0.7215E-14
    10   0.1405E-16   0.8741E-17   0.2279E-16
    11   0.2549E-19   0.2471E-19   0.5020E-19
    12   0.1861E-22   0.4194E-27   0.6055E-22
    13   0.1981E-26   0.2292E-25   0.2490E-25

 ACCUMULATED RUNOFF:                                     ACCUMULATED PESTICIDE LOSS:                            INSTANTANEOUS PESTICIDE LOSS
     WATER =            0.LITERS                              IN WATER =         0.0 GRAMS/HECTARE                          0.0 MICROGRAMS/LITER
  SEDIMENT =            0.KILOGRAMS                        ON SEDIMENT =         0.0 GRAMS/HECTARE                          0.0 MICROGRAMS/GRAM


 TOTAL WATER LOSS                                        % OF PESTICIDE APPLIED                                 RATE OF PESTICIDE LOSS
    FROM EVAPOTRANSPIRATION                                  IN WATER = 0.0                                             0.0 MICROGRAMS/LITER/HR
    =          0. LITERS                                  ON SEDIMENT = 0.0                                             0.0 MICROGRAMS/GRAM/HR

 ACCUMULATED INFILTRATION
 WATER LOSS =              0. LITERS

WATER BALANCE:
WATER IN =  0.7815300E 06 LITERS
WATER OUT = 0.7815529E 06 LITERS
 ZONE  1       INFILTRATION RATE=  0.1222E-03 CM/SEC
 ZONE  2       INFILTRATION RATE=  0.1222E-03 CM/SEC
 ZONE  3       INFILTRATION RATE=  0.1222E-03 CM/SEC
 ZONE  4       INFILTRATION RATE=  0.1222E-03 CM/SEC
 ZONE  5       INFILTRATION RATE=  0.1222E-03 CM/SEC
 ZONE  6       INFILTRATION RATE=  0.1222E-03 CM/SEC
 ZONE  7       INFILTRATION RATE=  0.1222E-03 CM/SEC
 ZONE  8       INFILTRATION RATE=  0.1222E-03 CM/SEC
 ZONE  9       INFILTRATION RATE=  0.1222E-03 CM/SEC
 ZONE 10       INFILTRATION RATE=  0.1222E-03 CM/SEC
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